Key concepts

This module presents the basics of building science that will help a remodeling contractor understand how houses function. Armed with this knowledge, remodelers can improve home performance.

Explanation

We will start with basic principles, then we will show how to use these principles in strategies to improve a remodeled home’s performance, and finally we will describe the various diagnostic tools and services available to help you make the best decisions during the remodeling process.

Action Items

Resources

Building Science Basics

Knowledge of building science can help remodelers improve the performance of homes

- Cost
- Comfort
- Durability
- Efficiency

2

Key concepts

Knowledge of building science basics can improve the performance of remodeled homes.

Explanation

Cost, comfort, durability, and efficiency (probably in this order) are the factors that a homeowner will most strongly relate to. Therefore you will also be thinking in these terms.

Making homes more energy efficient does not always cost more; sometimes the initial cost of an efficient remodeling project can be less. On a monthly basis, it usually costs less to own an efficient home when both initial and utility costs are included.

Action Items

Resources

Topics Covered

- Building science definition
- What matters to the homeowner
- What matters to the house—flows of heat, air, and moisture
- Environment's impact on occupant and house
- Break
- Controlling flows of heat, air, and moisture
- Trade-offs – getting the most "bang for the buck"
- Diagnostic tools for contractors

3

Key concepts

This module takes several hours to present. It includes both lecture material and in-class example problems for students. There will be a break near the mid-point of the training session.

Explanation

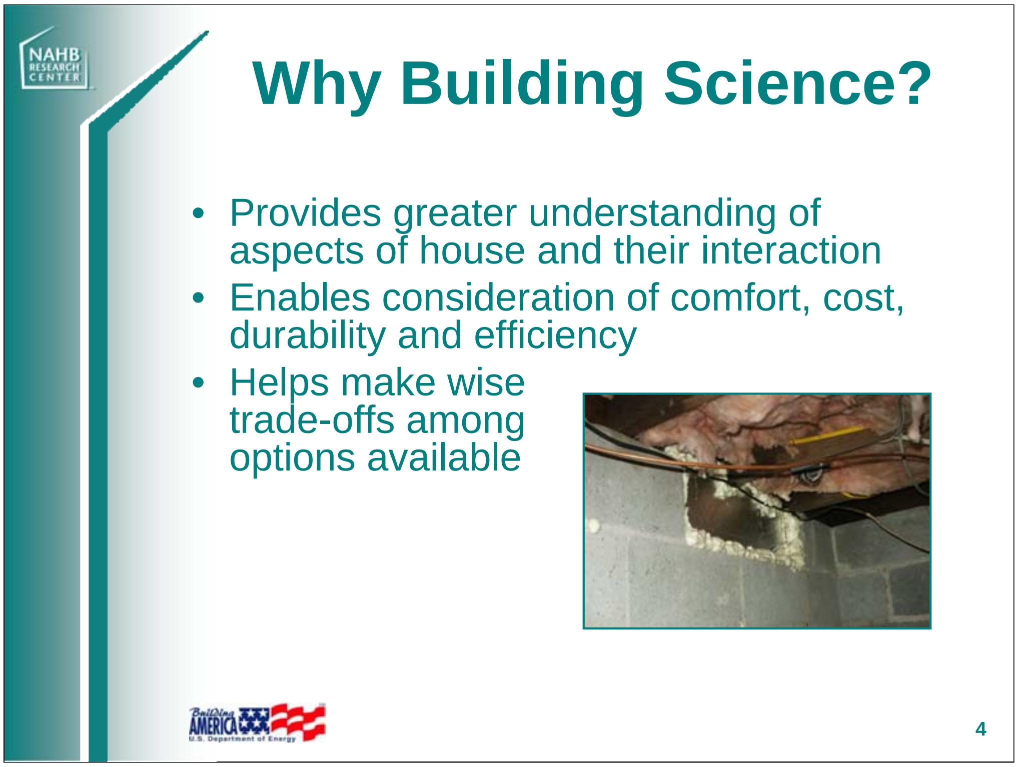
By understanding building science principles, you will be able to reduce or eliminate potential problems in remodeling projects.

Example building science-related problem (see photo): Vinyl wall covering can stop the flow of water vapor when humid air or liquid water enters a wall cavity—thereby preventing the wall assembly from drying toward the inside. Trapped moisture, along with the wall covering adhesive and drywall paper backing (food sources for mold), can create major mold problems.

This module will help you understand the flow of air, energy, and moisture within homes and thereby reduce the potential for "nasty" problems resulting from your work.

Action Items

Resources



Key concepts

By understanding building science, you attain a greater understanding of various aspects of houses and their interaction. This understanding will enable you to evaluate comfort, cost, durability and efficiency, and to make wise trade-offs between the options that are available.

Explanation

Renovation contractors (RC) get to see houses that are many years old and that have often been through numerous modifications and repairs. As a result, RCs are often presented with 'mysteries' in homes that other professionals have not been able to diagnose or solve properly. Often challenged with undertaking a major renovation or set of repairs, RCs have an opportunity to apply building science concepts to ensure that their work makes the house more durable, comfortable, and energy efficient, while ensuring the home is no less safe or prone to more problems after the work is complete.

Action Items

Resources

Building Science Definition

A.K.A. *building physics* or *building dynamics*

The study of the interaction between
- Occupants
- Building components/systems, and
- Environment

Focusing on flows of
- Heat
- Air
- Moisture

5

Key concepts

Building science is the study of the interaction between occupants, building components/systems, and the surrounding environment. It focuses on the flows of heat, air, and moisture.

Explanation

While building science may also be called building physics or building dynamics, all the terms refer to the use of a scientific approach to understanding cause and effect between the elements of a house. The scientific approach involves applying the principles of physics to a home, collecting information about various characteristics of the home, analyzing that information, developing and implementing a plan of action based on that analysis, and finally evaluating the success of that plan. Typically, builders and remodelers don’t have time to do this type of analysis. Luckily, there are several simple software programs that builders can use. There are also several programs and companies throughout the country that do this type of analysis, such as Building America (www.buildingamerica.gov) and the ENERGY STAR™ Program (www.energystar.org.). The Introduction and Marketing module and the House As A System module have information about some of the available software tools.

Depending on the issues being considered, the scientific approach can take as little as a few moments and be completed in your head, or it could take several hours and require the support of a computer. The more you use the scientific approach and practically apply the principles you learn here, the less time it will typically take.

Occupant Focus

Comfort issues
- Even temperatures, no drafts
- Healthy humidity levels (winter and summer)
- Mold and other allergens

Cost issues
- Remodeling project
- Energy, maintenance and repair costs

6

Key concepts

The best place to start is with the issues of importance to the home owners (your customers).

Explanation

Beyond the pure aesthetics and functionality of their homes, homeowners usually list these concerns for improving their home. At the same time, owners of older homes assume that some ‘issues’ or ‘problems’ are simply part of owning an older home and are not fixable. A building science-related approach can create solutions to these issues and problems.

Older, leakier homes, and homes retrofitted with an air conditioning system usually have some comfort issues, as do most two-story homes with a single mechanical system**.**

It is often accepted that homes will be “very dry” during the winter in heating climates. High humidity levels (that encourage mold growth) are also often accepted during the summer in cooling climates. Both situations can be overcome by a better focus on building science.

Many solutions to mold and other allergens are sold to the public as ‘magic bullets’, like high tech filtration, electronic or ionization air cleaning, duct cleaning, and ultraviolet lights inserted inside duct systems. These approaches are usually bandaids at best and can diminish air quality at worst. Often, the medical community supports these types of solutions because they don’t understand building science.

Building science-related issues–damp insulation, leaky homes, and ineffective drainage and water maintenance–can cause high operating and

Moisture Levels

Building decay ……………………….……. 100% RH
Interior mold……………………….……… RH > 70%
Dust mites…………………………...…… RH > 50%
Static electricity and dry sinus ..……….. RH < 25%

Ideal Health & Comfort is 30%-50% RH at room temperature (~72° F)

7

Key concepts

Liquid water (a.k.a. bulk moisture) and water vapor can raise home humidity levels. As humidity levels rise, the house itself, as well as the home's contents, absorb moisture. Inappropriate moisture levels (too high or too low) can cause significant problems for the homeowner such as building decay and mold.

Explanation

Relative humidity (RH) levels above 100% can cause building materials to decay due to fungus (wood rot).

RH levels in the air above 70% support the growth of mold.

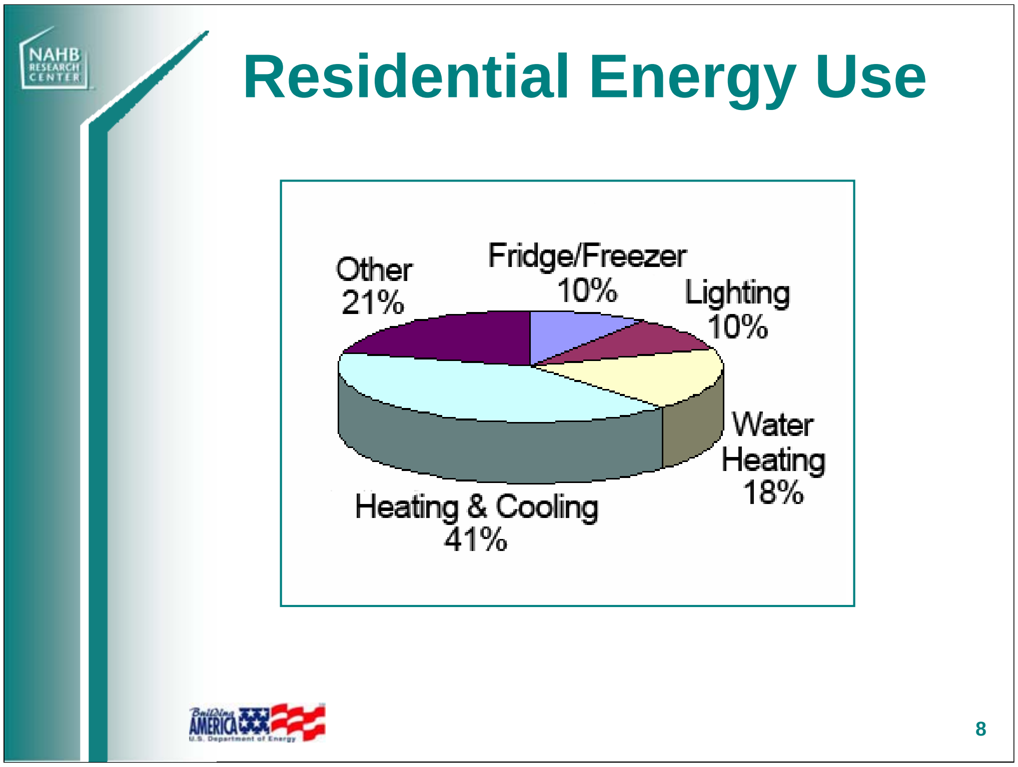
RH levels in the air above 50% relative humidity support dust mites, one of the most common human allergens.

Dry homes (RH <25%), particularly in winter, cause static electricity, dry sinuses and uncomfortable breathing for the occupants.

The ideal RH of 30-50% at room temperature is most easily attained when liquid water is eliminated and when indoor humidity is controlled with tight building envelopes, ventilation at the source of water vapor (e.g., baths, kitchen, laundry) and properly sized space conditioning equipment.

Photo: Dust mite (not actual size!)

Action Items



Key concepts

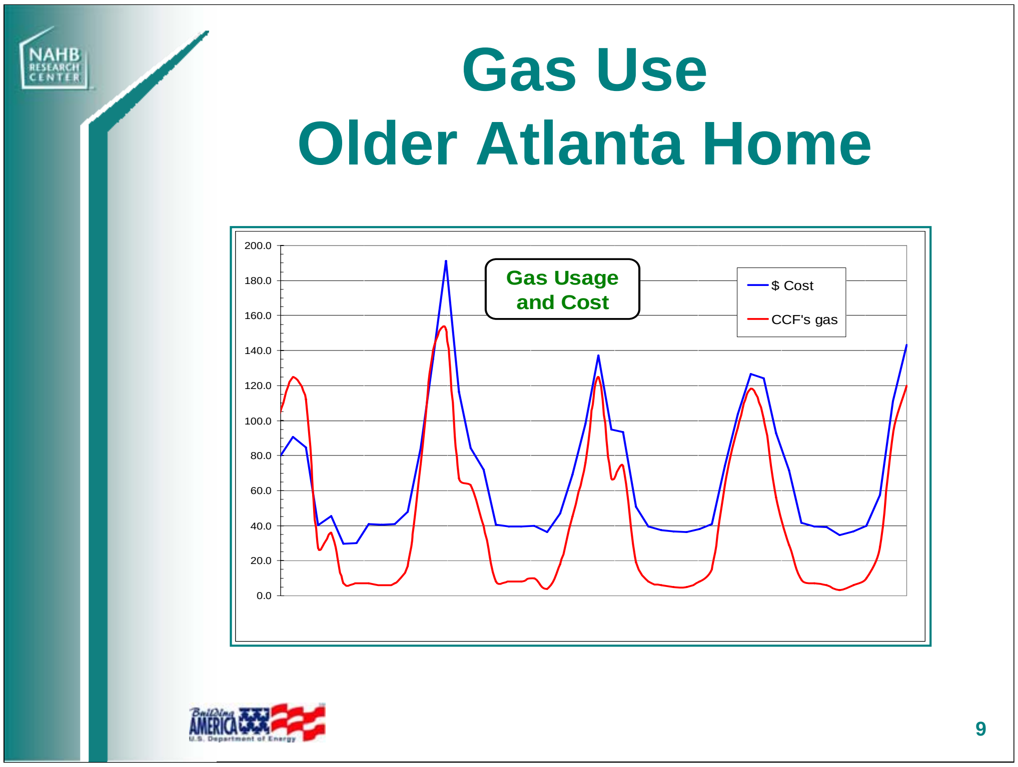
Heating and cooling typically makes up the largest portion of utility cost and, therefore, presents the greatest opportunity for reducing a home's utility costs.

Explanation

In a typical Southeastern U.S. house, approximately 41% of total energy costs are spent to maintain the indoor temperature at thermostat settings. Water heating is the second largest energy user. Other home energy uses include plug loads (things that are plugged into walls) and other appliances.

Action Items

Resources



Key concepts

Studying a utility bill can provide valuable information about a home's performance.

Explanation

Peaks on chart (showing five years of gas use) represent increase in gas use due to winter heating. Peaks decreased for two years while the owner (a Southface Energy Institute Employee), made progressive improvements in air tightness, duct tightness, and insulation levels. Usage is climbing in the last year because, with a new baby in the home, the thermostat setpoint has been kept higher and they are not using setback as much. Varying peaks may also represent weather conditions.

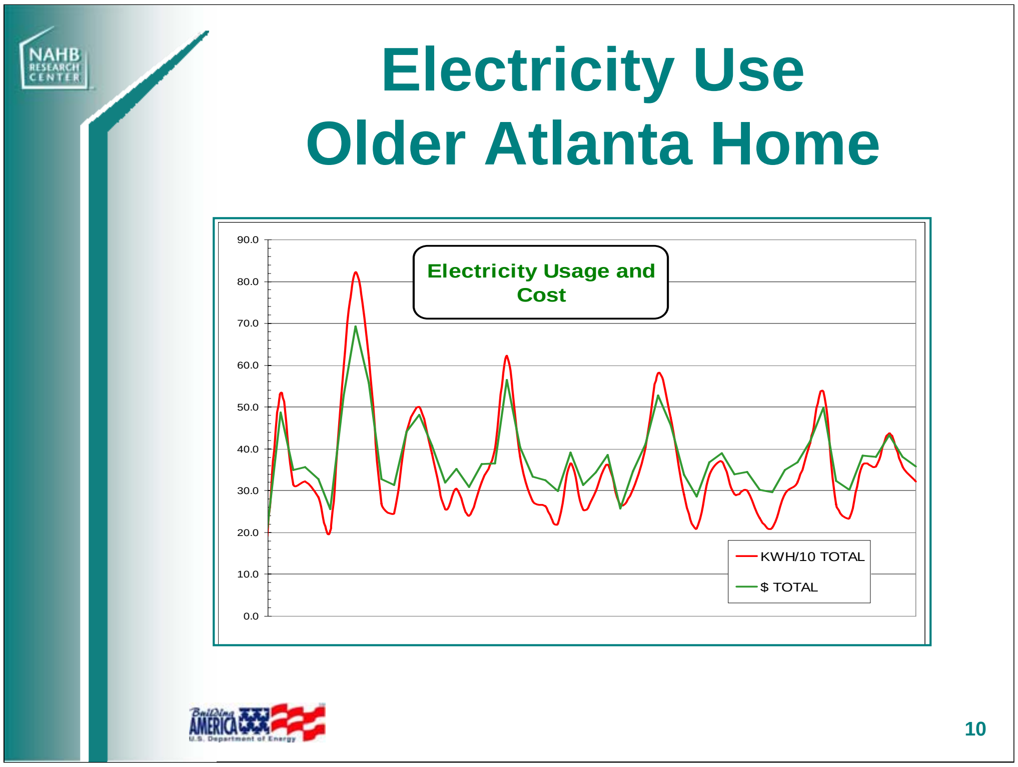
Usage levels in between peaks is the base usage level – the gas usage for other loads such as water heating, range, and gas dryer.

Action Items

Ask you customer to show you their utility bills for the past year, if they are available.

Resources

An online software tool, Home Energy Yardstick, compares utility bills with other similar houses. See http://www.energystar.gov/index.cfm?c=home_energy_yardstick.index



Key Concepts

Explanation

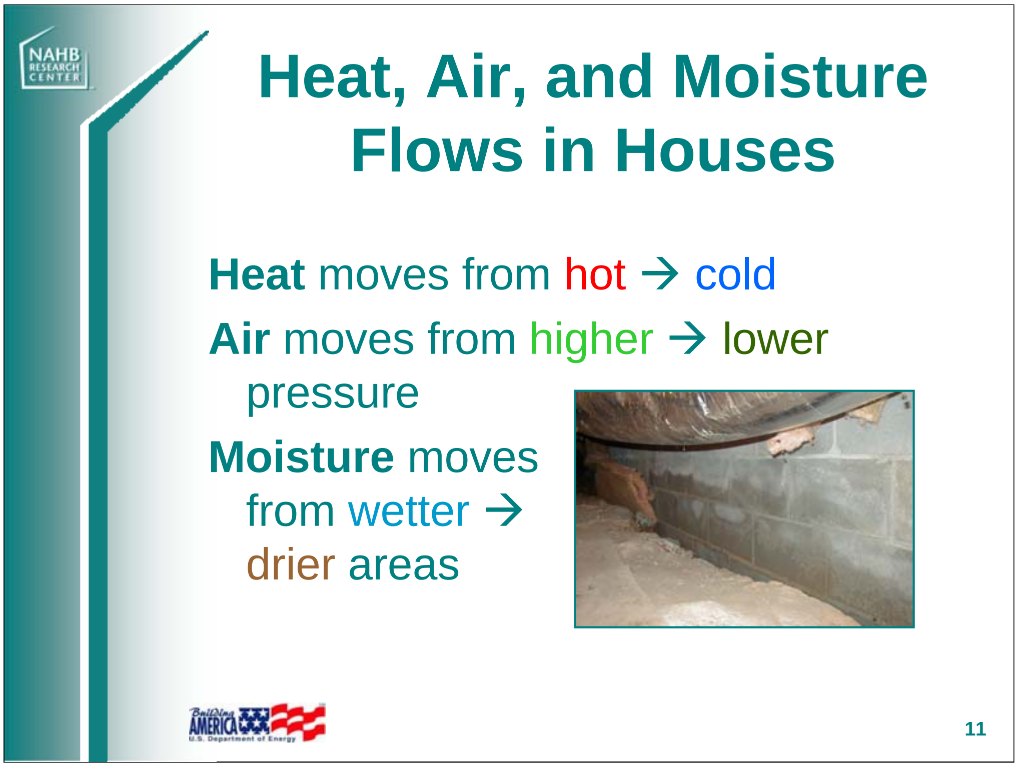
Major peaks represent summer electricity use – mainly due to air conditioner use. Note that the peaks declined in three consecutive summers, both because of improvements noted on previous slide and because two of these summers were milder than normal.

Secondary peaks represent high furnace usage in winter – the power consumed by the furnace blower.

Months without heating or cooling usage represent the base load which includes lighting and appliances.

Action Items

Resources



Key concepts

Heat, air, and moisture flows are governed by the laws of physics.

Explanation

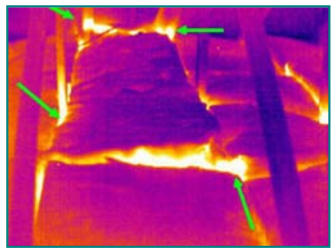
EXAMPLE: The photo shows the movement of water in the block foundation wall from a wetter area on the outside to a drier area on the interior crawl space

Action Items

Resources

Heat Flow

- Conduction
- Convection
- Radiation



12

Key concepts

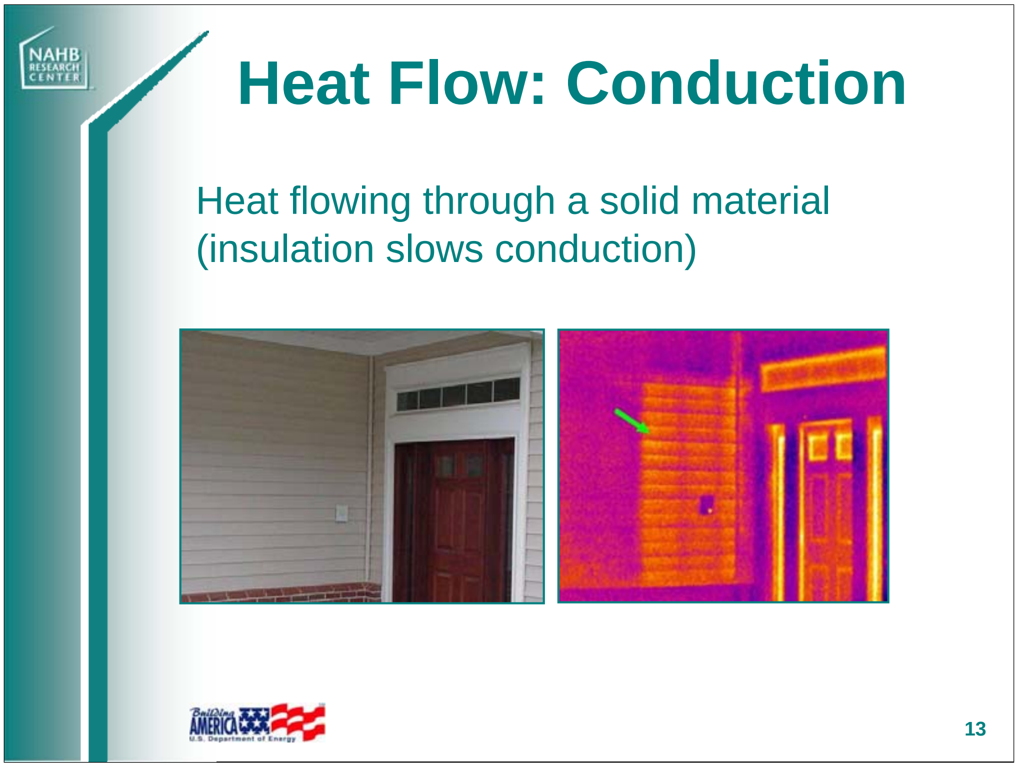
Heat flows by three means: conduction, convection and radiation.

Explanation

Photo: infrared photo of heat flow through gaps around insulation batts in an attic (the yellow color indicates more heat flow). When batts are not properly installed the insulation's effectiveness can be significantly reduced.

Action Items

Resources



Key concepts

Conduction is heat flowing through a solid material.

Explanation

The picture at right is an infrared scan of the photo at left during the heating season.

The brighter colors show areas with higher rates of heat flow (blue is colder, yellow is hotter). Can you tell which portion of the wall is uninsulated? Note that the unisulated portion of the wall is the same color as much of the glass in and around the door!

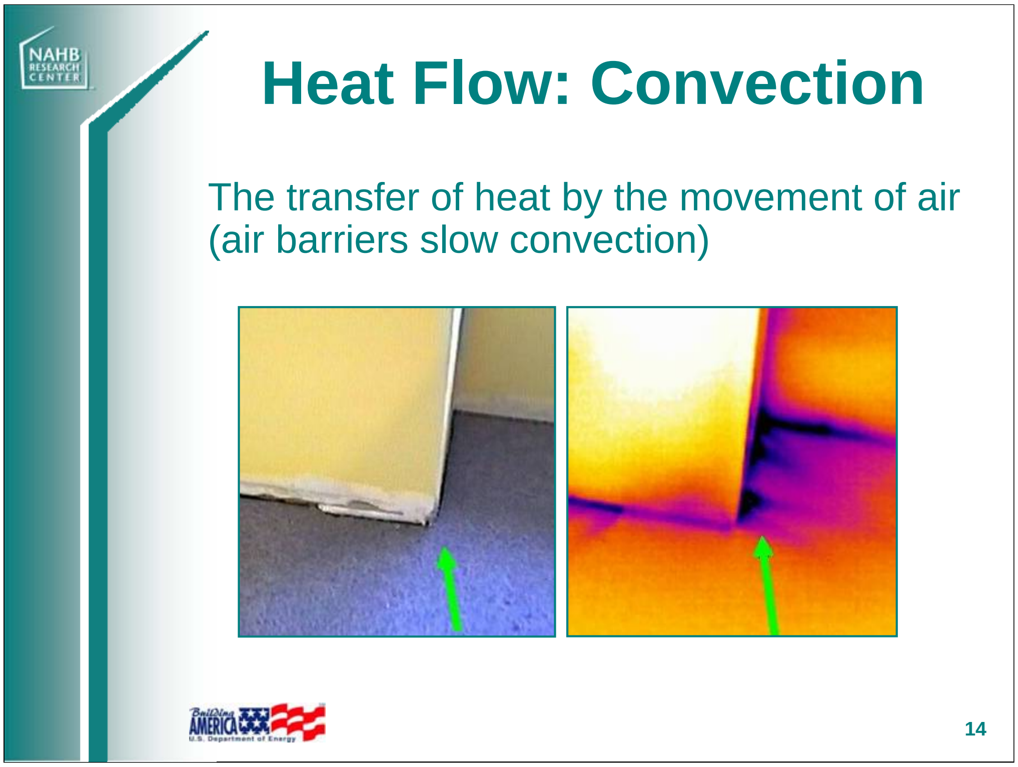
In the insulated wall, heat must conduct through insulation (which contains millions of tiny air pockets that slow conduction. Heat flow through insulation is a relatively slow process compared to conduction and convection through the uninsulated wall–which has an open airspace that transmits heat readily.

Action Items

Resources

Instructor's Notes

Is wood framing a good insulator? How can you tell?



Key concepts

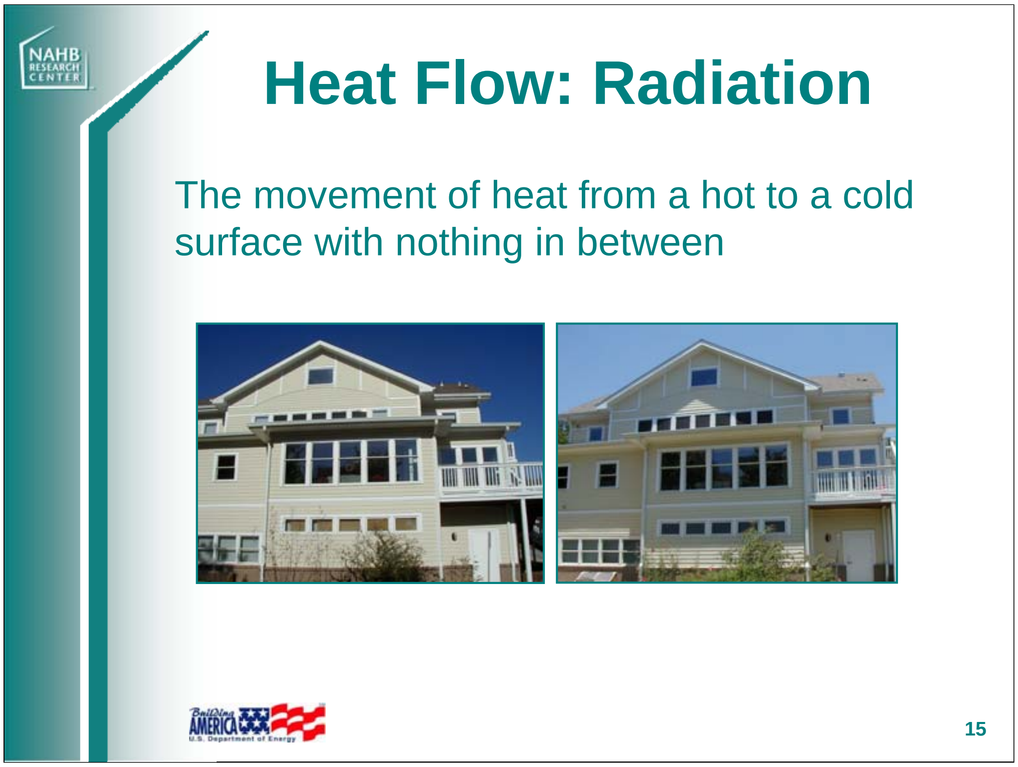
Convection is the transfer of heat by the movement of a fluid (air).

Explanation

The photos show the effect of air movement under the wall's bottom plate in the winter months when the air is colder than the surrounding surfaces. (Blue indicates colder temperature.)

Action Items

Resources



Key concepts

Radiation is the movement of heat from a hot to a cold surface with nothing in between.

Explanation

Sunlight is a major source of radiation heat gain in homes.

The photos show the south elevation of the Southface Energy Institute building during the winter (left) and summer (right) solstices and the effect on the building. Passive solar design reduces space conditioning needs by allowing solar heat gain through windows in the winter but blocking gain by shading in the summer.

Low-emitting surfaces reflect and retard radiation (either solar radiation away from the building or heat energy back into the building).

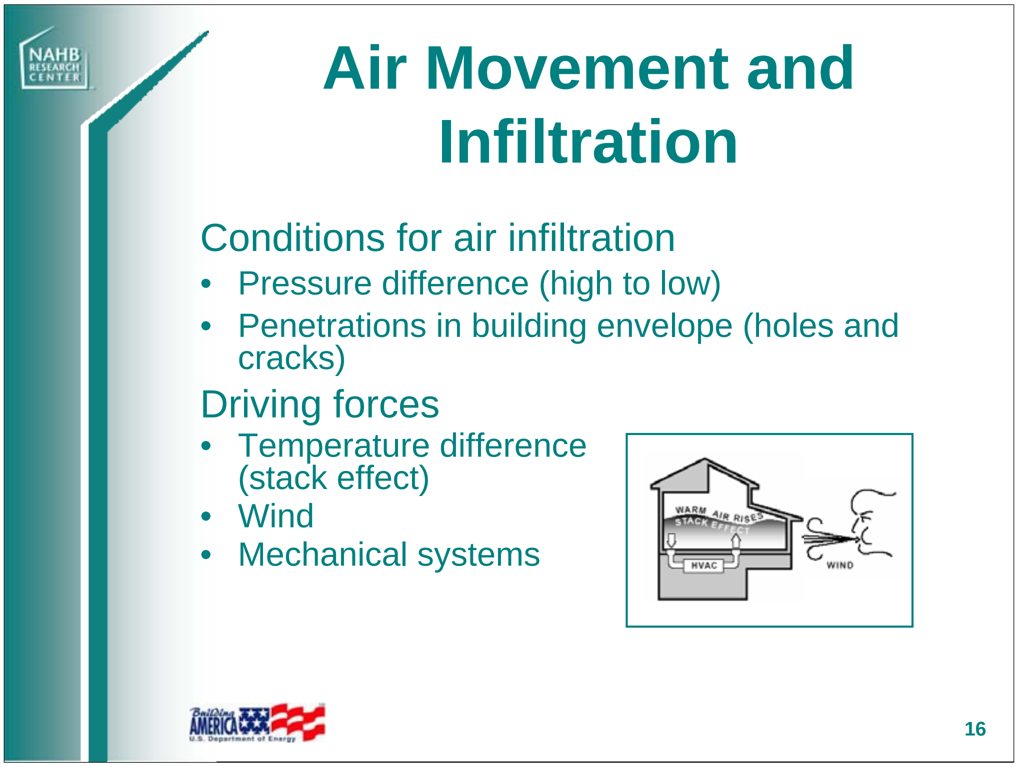
Action Items

Look for ways to beneficially use or exclude radiant heat from your project. This topic will be discussed in more detail in other modules.

Resources

Michael Crosbie, 1997, The Passive Solar Design and Construction Handbook (textbook), John Wiley & Sons.

Passive Solar Design (2000), Four-page fact sheet that discusses how passive solar design features can increase energy efficiency and comfort



Key concepts

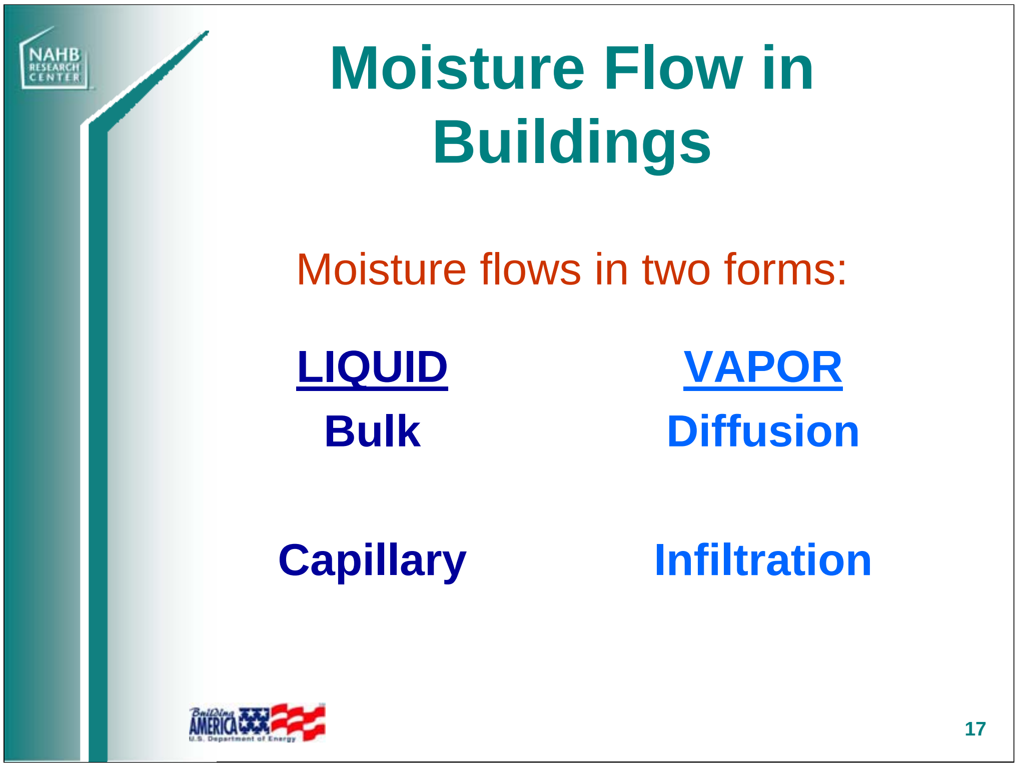
For air movement into or out of a house, two conditions must be present: a pressure difference (air moves from higher to lower pressure) and a hole or other penetration. The amount of air movement depends directly on the pressure difference and the size of the opening.

Explanation

A pressure difference between inside and outside a home is created, in part, by the "stack effect." The stack effect refers to the phenomenon of warm air rising in a structure and colder air sinking; the effect becomes more pronounced as the height of a building increases. The stack effect creates a higher pressure at the top of a structure with respect to the outdoors (driving air out of the building, or exfiltration) and a low pressure at the bottom of the structure (sucking air into the building, or infiltration).

Wind creates pressure zones around the exterior of a building to drive air leakage in and out of the building. The windward side of a building will be at a higher pressure, while the leeward side generally has a lower pressure.

Mechanical fans create pressure differentials inside the building that can create air leakage. Exhaust fans and appliances can encourage infiltration of air by creating a negative pressure within the home: a clothes dryer exhausts approximately 200 cfm, kitchen exhaust fans move 300 to 1500 cfm. Furnace blowers move between 600 and 2400 cfm and become a problem when duct systems or the house itself is leaky. If pressure differences are caused by the operation of the air handler, air leakage can increase as a result. A Florida study showed that infiltration rates doubled in many homes when the HVAC blower was operating. More about duct leakage and fan



Key concepts

Moisture flow in buildings occurs in two forms – liquid and vapor.

Explanation

Liquid water is usually more of a concern than water vapor in houses because it can create water damage to materials and contents of the home. Examples include rain or plumbing leaks.

Capillary flow of moisture is the wicking through porous materials like concrete, cellulose insulation, wood. Capillary moisture is perhaps most often noticed on basement walls and floors.

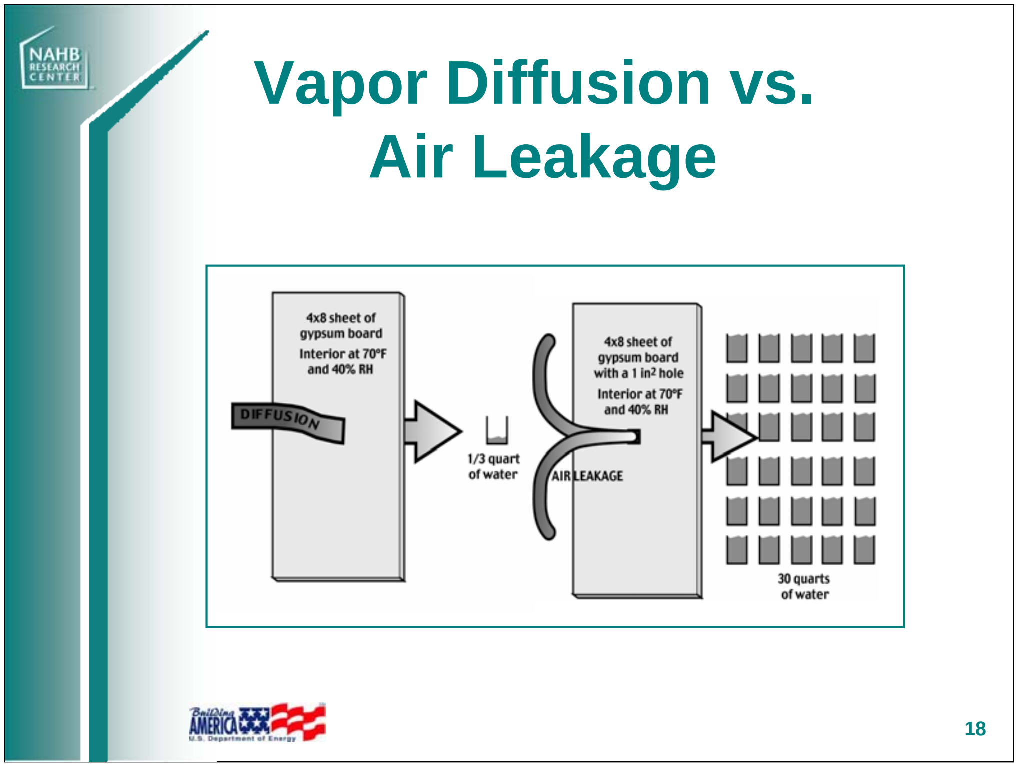
Diffusion – molecules of water move through porous materials. Diffusion of moisture is most frequently noticed when an improperly installed vapor barrier (or poorly insulated wall) causes water vapor to condense on the barrier becoming a "bulk water" issue. Trapping water vapor in a structure can create many long-term problems including rot, mold, and an environment conducive to termites, cockroaches, and other pests.

Houses in humid climates have to deal effectively with moisture laden outside air that enters the structure. In addition to contributing to long-term problems noted above, excess humidity greatly affects occupant comfort.

Action Items

Resources

Read This Before You Design, Build, or Renovate



Key concepts

Air leakage is the primary way in which water vapor enters a home. Air coming into (or out of) a home carries a lot of water vapor with it. Infiltration has a much greater impact than vapor diffusion (transport of water vapor through a material) on the amount of moisture entering a home.

Explanation

Let's compare the impact of vapor transport through an unsealed 4x8 sheet of gypsum wallboard by diffusion with the impact of vapor transport due to air leakage. Air leakage through a 1 square inch hole transports 90 times more moisture than diffusion through the entire 4x8 sheet of gypsum wallboard.

A lot of emphasis is often placed on moisture transport via diffusion (e.g., vapor barriers). However, for all but the most severe heating dominated climates, it is much more important to prevent air leakage in order to minimize water vapor.

Action Items

Resources

Key concepts

Bulk water problems are often undetected until significant problems are created.

Explanation

Left photo: drip from plumbing leak saturated the foundation wall and floor of this crawlspace.

Center photo: cracks in stucco cladding allow water in but don't often let the wall dry out completely, causing rot and structural damage.

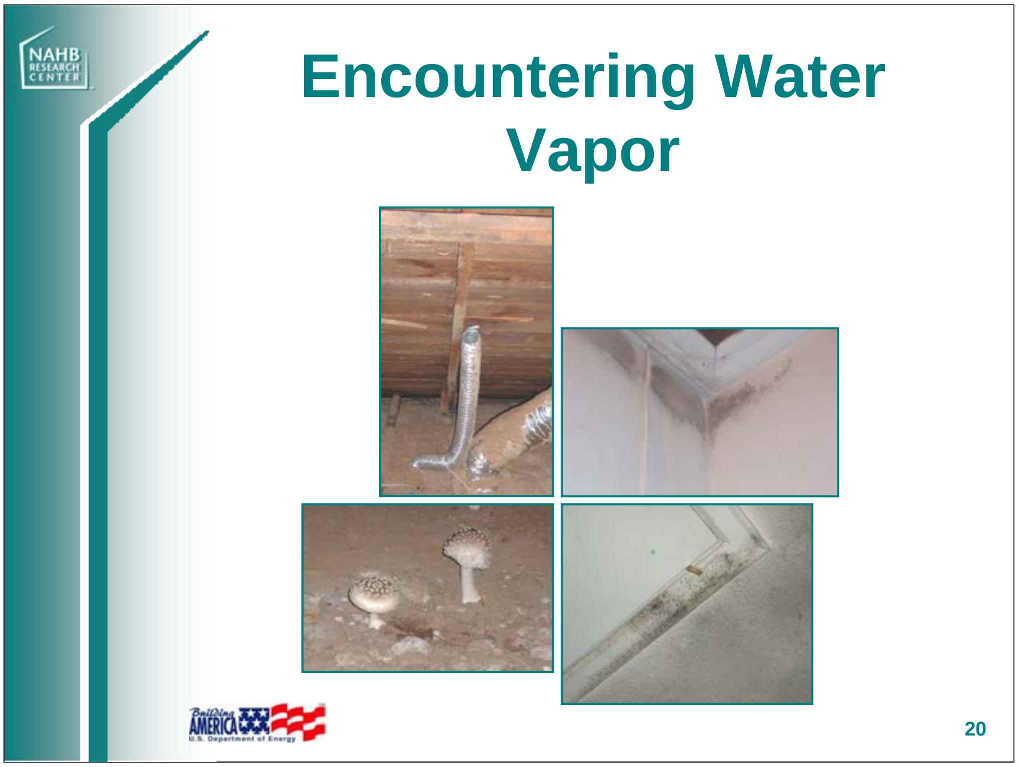
Right photo: foundation wall leakage has created high humidity in the basement and damaged wood and metal structural members in contact with the concrete floor.

Action Items

Look for evidence of bulk moisture problems in the house being remodeled and point them out to the homeowner. Be ready to offer potential solutions.

Resources

Water Management Guide by Joseph W. Lstiburek – Available from the Energy and Environmental Building Association, www.eeba.org.



Key concepts

Water vapor is usually noticed in homes when building surfaces cool below the air's dew point, causing the water vapor to condense on the cool surface. This moisture can cause mold and fungus deterioration. In addition, high interior humidity in the warm summer months can make a home feel uncomfortable and cause occupants to lower thermostat settings to achieve the same level of comfort.

Explanation

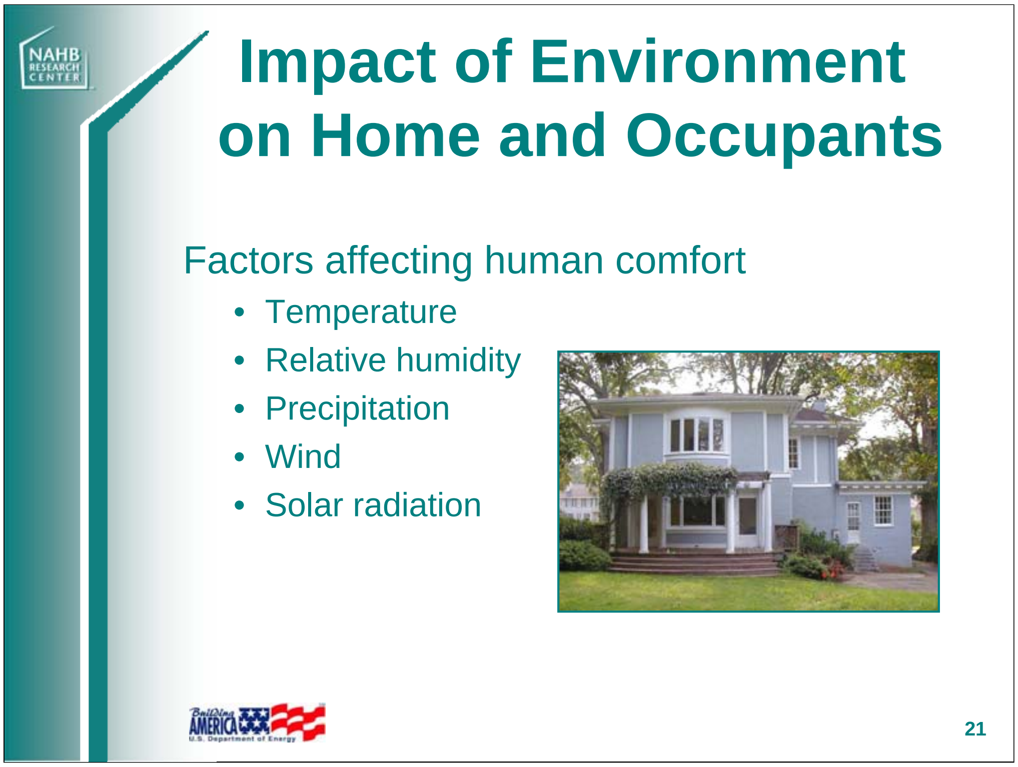
Top left photo: bath exhaust fan terminated in the attic causes mold growth on the roof deck underside.

Right photos: air leakage at attic access panels coupled with air pressure differentials caused condensation on cold surfaces which resulted in mold growth.

Bottom left photo: crawlspace dirt dry to the touch can be a pathway for evaporation – while this dirt feels dry it is supporting fungus growth.

Action Items

Look for signs of moisture such as darkened surfaces either in the living space or in the attic or basement. The underside of roof sheathing may show water stains or be a darker color. Likewise, insulation that has been wet or damp will also be dark or black-colored. Peeling paint on a wall or ceiling surface or windowsill may be a sign of moisture.



Key concepts

Factors affecting human comfort include: temperature, relative humidity, rain, wind, and the sun.

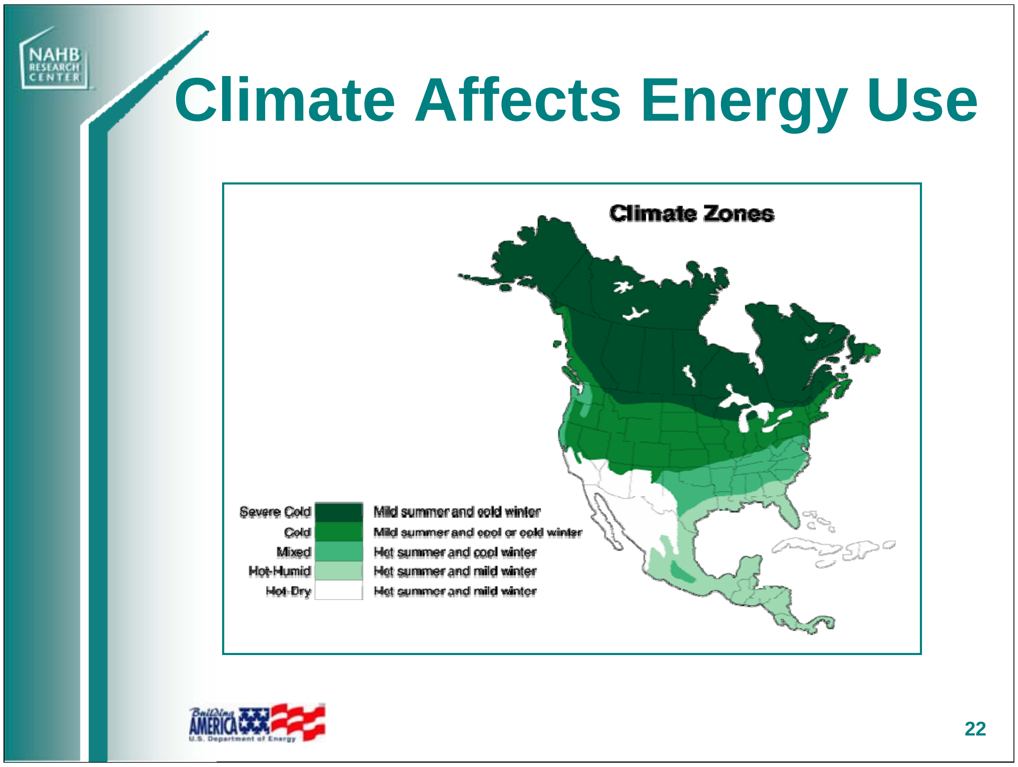
Explanation

People are comfortable in a relatively narrow range of temperature and relative humidity. This preferred comfort range has narrowed as people's expectations of thermal comfort have become higher – in the South, virtually all new homes include air conditioning. Preferred temperature range is between 65 and 80 degrees Fahrenheit; preferred RH range is 35 to 70%. As shown in Slide 8, about 40% of a typical home's energy use is for maintaining indoor temperature.

People are more comfortable at lower temperatures as the RH increases and air circulation is reduced. Conversely, people are more comfortable at higher temperatures when RH is lower and when air circulation is increased which improves evaporation off skin.

Factors such as wind, sun, and precipitation also affect comfort. Direct solar radiation helps a person feel warmer in the winter on a sunny day, and wind makes people feel cooler. Precipitation makes people feel cooler by increasing evaporative cooling from the skin's surface.

In most of the U.S., solar heat gain through glass is welcome in the winter months but not in the summer. South-facing glass can maximize winter solar gain. In mixed and hot climates, minimizing east and west glazing helps to minimize solar heat gain.



Key concepts

Climate has an enormous impact on energy consumption

Explanation

Message: you can't build the same way everywhere. Home renovation TV shows are often located in cold or severe cold climates. Lessons applied there don't always work in other areas of country.

In northern heating climates, the primary concern is winter heating load and how to keep warm. In the Southwest, it is all about cooling and moisture is not a concern. Along the Gulf Coast and Atlantic Coast, the concerns are heat and humidity. In the mixed climate area, heating and cooling season humidity are concerns.

•Severe Cold… >= 8,000 HDD

•Cold… > 4,600 HDD and < 8,000 HDD

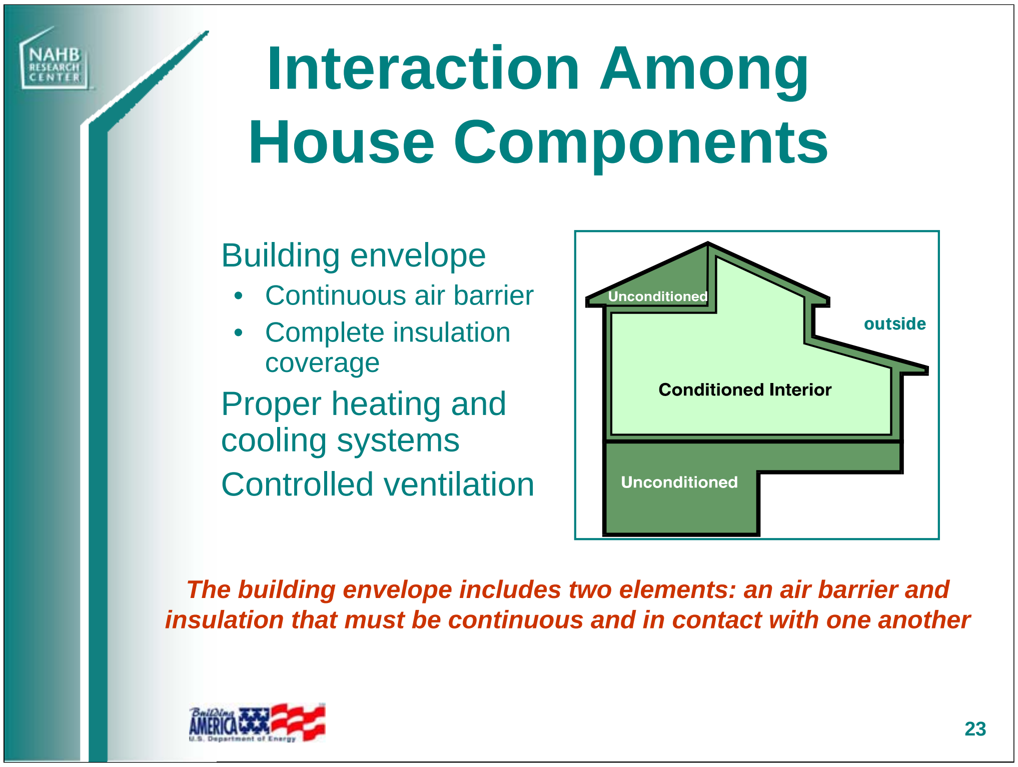
•Mixed Humid… < 4,600 HDD and more than 20 inches of rain per year; average monthly winter temperature drops below 45°F

•Hot Humid… < 4,600 HDD and more than 20 inches of rain per year; average monthly winter temperature stays above 46°F

•Hot Dry/Mixed Dry… <4,600 HDD and less than 20 inches of rain per year; Hot-Dry average monthly winter temperature above 46°F, Mixed-Dry average monthly winter temperature drops below 45°F

Action Items

Determine which climate zone you are building in

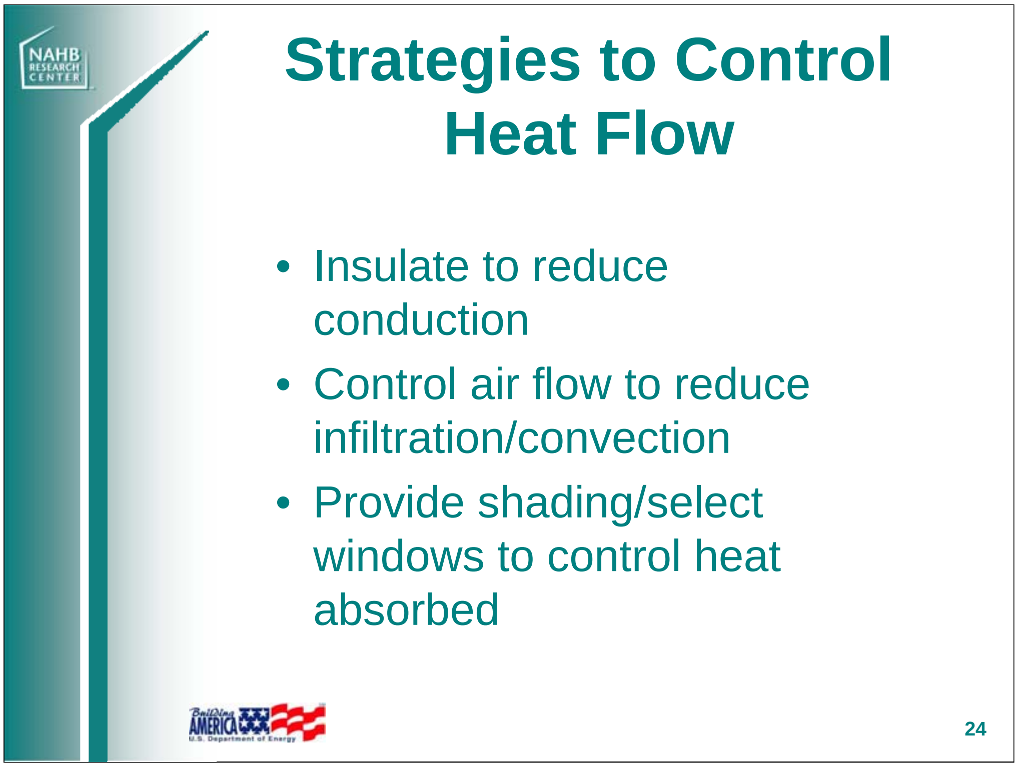


Key Concepts
The interaction of the building envelope, heating and cooling systems, and ventilation impact house performance.

Explanation
The interaction of heat, air, and moisture in a home affects the building envelope. The combination of air and thermal barriers that define the conditioned area of a home must be continuous and in contact with one another for optimum efficiency and occupant comfort. Good envelopes withstand the flows of heat, air, and moisture. Homes with good envelopes are more efficient, more comfortable, have improved air quality.
The envelope interacts with the heating and cooling system (a good system is one that is sized, designed, installed, and maintained properly) – heating and cooling systems do their job more effectively and efficiently when envelopes are complete.
In a well-built home, tight construction seals pollutants out and mechanical ventilation provides a planned amount of fresh air for occupants. This is a better approach than relying on unintentional ventilation in leakier homes. By knowing approximately how much air will enter a home, mechanical equipment can be designed and selected to handle moisture effectively.

Action Items
Make sure that the air barrier and insulation are continuous and in contact with one another in your projects.

Resources
Air Barrier Association http://www.airbarrier.org/



Key concepts

There are three major strategies to control heat flow.

Explanation

The strategies you should consider include:

•Insulate to reduce conduction

•Control air flow to reduce infiltration/convection

•Control radiation to moderate the amount of heat absorbed

Action Items

Resources

Insulate to Reduce Conduction

25

Key Concepts

Insulation helps slow the flow of heat into and out of a home.

Explanation

Batt insulation's tiny fibers trap air. This trapped, still air is the main reason for insulation's ability to slow heat transfer. Batt insulation works best in a sealed wall cavity because, when air can circulate around and through batts, their insulative ability is greatly reduced.

A material's ability to slow heat flow is measured by its resistance or R-value. The higher the R-value, the greater is the resistance to heat flow. A related concept is U-value, or a measure of a material's conductance. U-value is the inverse of R-value. A material having a lower U value will conduct heat more slowly than one having a high U-value (the highest U-value is 1). Windows are typically rated by U-value, while most insulation products are rated by R-value. A material with an R value of 13 has a U of 1/13, or 0.08.

Batt insulation should not be compressed and should completely fill a wall cavity. Insulation should be cut to neatly fit around electrical boxes and wiring. Compressed insulation and gaps in insulation lead to increased energy loss.

Photo: where are the problems with this insulation installation? (missing cavities in wall and floor, compression, gaps, beam not insulated, floor insulation installed upside down).

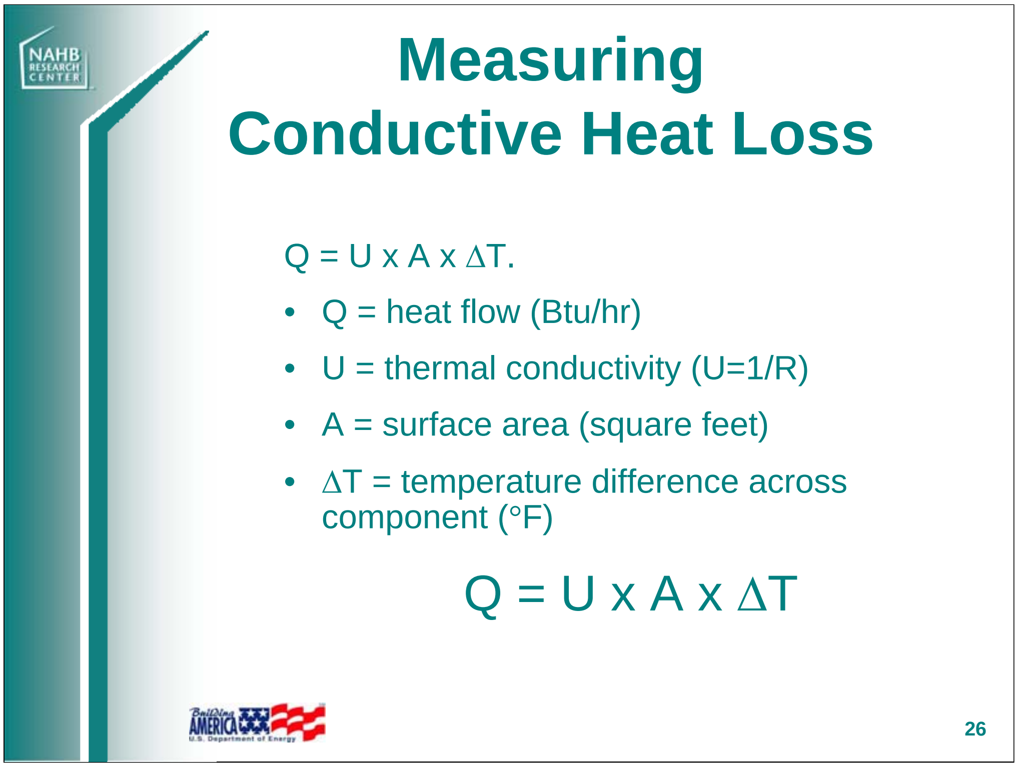
Action Items

Where insulation is visible, such as in an attic or basement, note the depth and R-value of the insulation as well as the quality of the installation. This may provide an indication of what is behind the wall.

See the U.S. Department of Energy Website below to check existing R-values against recommended R-values.

Resources

http://www.eere.energy.gov/consumerinfo/energy_savers/r-value_map.html – U.S. DOE recommended R-values for various locations.



Key concepts

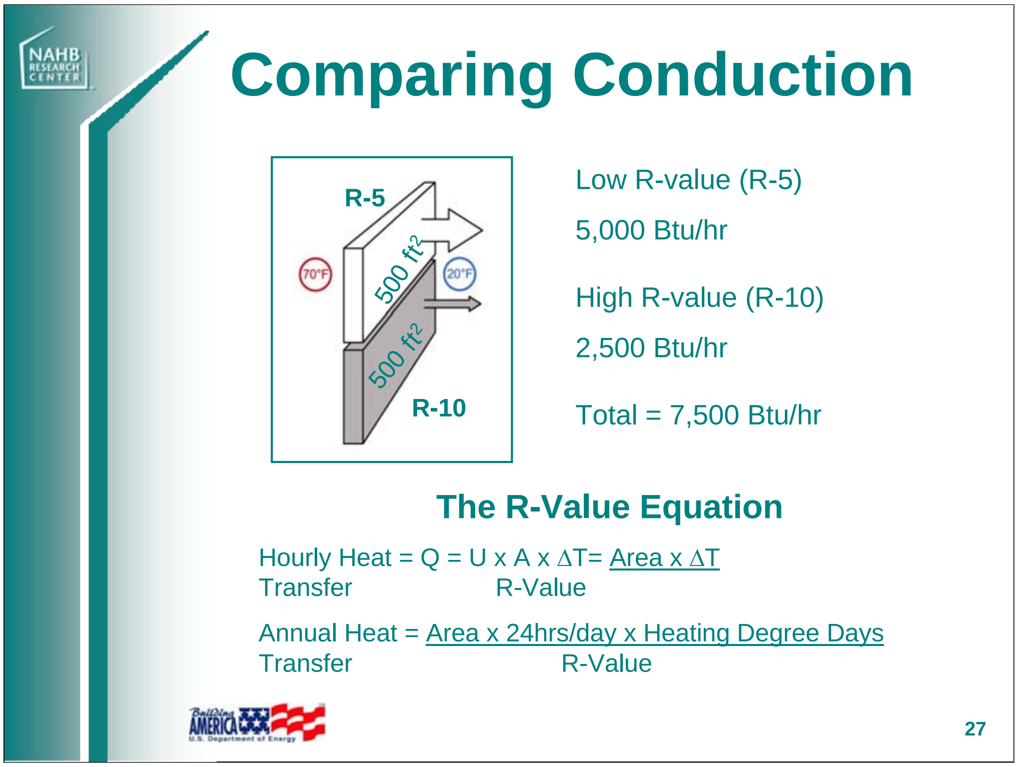
The energy loss through a material (e.g., wall or building envelope) is directly proportional to its surface area, U value, and the temperature difference across the material.

Explanation

As surface area increases, R-value decreases, or temperature difference increases, the amount of energy lost increases. As a contractor, generally speaking, you will only be able to impact the R-value of the materials. Therefore it is important to select appropriate values considering the impact of the other two factors.

Action Items

Resources



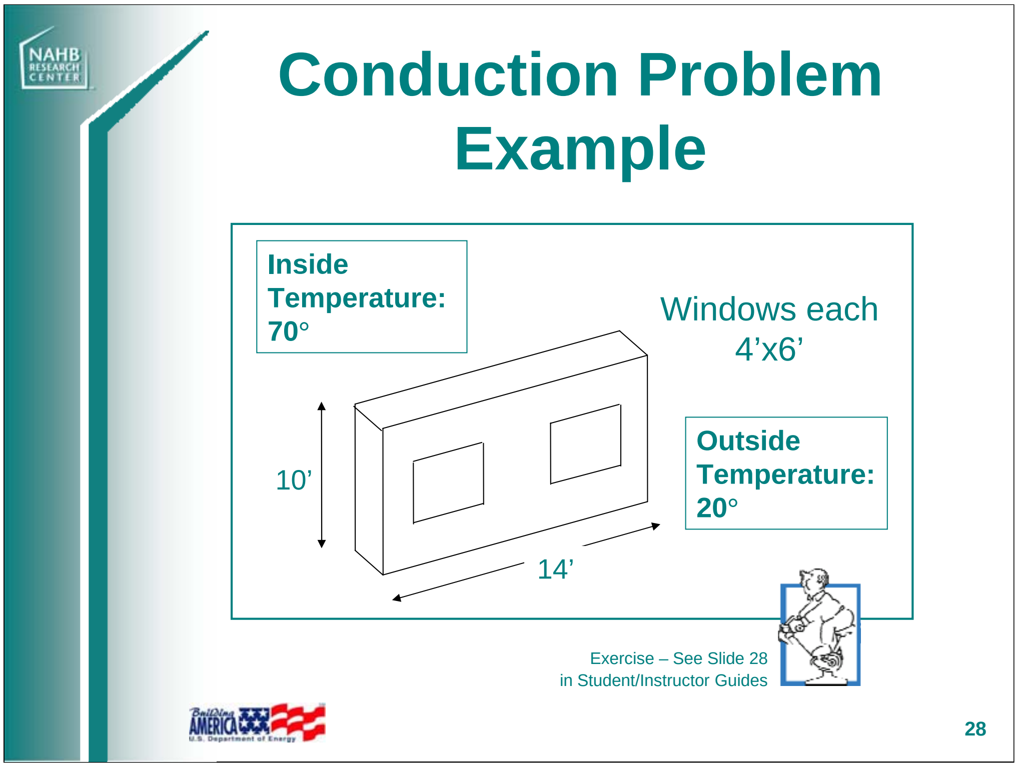
Key concepts

Calculate conduction heat loss through a wall section

Explanation

A 500 SF wall assembly with an R-5 conducts 5000 BTU/hr, doubling its R-value reduces its conductance by half. Two wall sections having different R-values are calculated separately and added together when determining heat loss. The heat transfer through any house assembly (wall, ceiling, floor, etc.) is proportional to the area of the assembly, the temperature difference across the assembly, and the Rvalue.

The annual heat transfer is simply the extension of the hourly heat loss across the entire heating season. Heating Degree Days are a measure of the severity of the heating season. A degree-day is a unit that represents a 1º F deviation from a fixed reference point – usually 65º F in the mean daily outdoor temperature. The assumption is that one will need to add supplemental heat when the outdoor temperature drops below 65º F. If the average outdoor temperature is 40º F for one day, 25 degree days have accumulated. If the average outdoor temperature is 60º F for five days, 25 degree days have also accumulated. The number of degree days is multiplied by 24 hours to obtain the total degree hours over the period of interest. Atlanta has 2,961 heating degree days. Seattle, WA has 4,424 heating degree days, and Minneapolis, MN has 8,382. Cooling degree days are calculated in a similar fashion.



Example conduction problem:

Let's look at an existing exterior wall example - make it uninsulated in Atlanta (believable there), with single pane, 50-year old, deteriorated wood windows with no storm sash.

What is best strategy for improving the wall's overall performance?

Which has greater impact – upgrading insulation or windows?

Which is more cost effective?

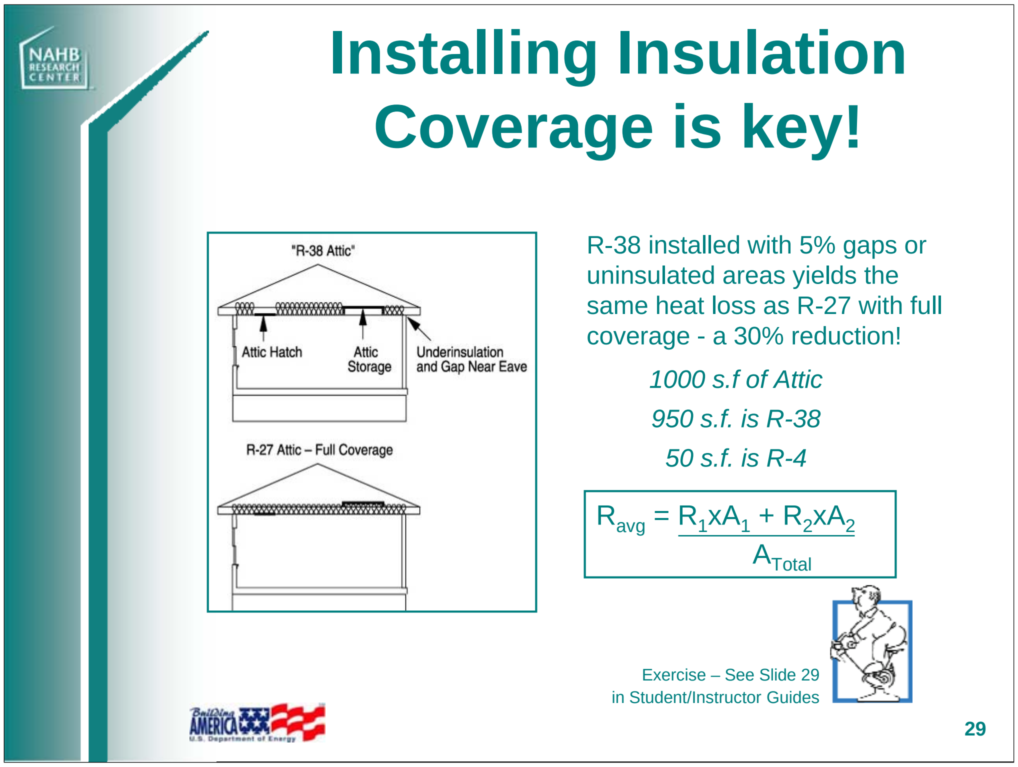
In a wall assembly calculate the heat flows for different materials to get the total heat flow for the assembly.

•Problem 1: The wall R-value is assumed to be 3, the window R-value is 1. What is the total heat flow of the existing wall?

•Answer 1: Wall = (1/3 Btu/s.f./deg F) x (92 s.f.) x (50 deg F) = 1518 Btu/hr; Window = 1/1 Btu/s.f./deg F) x (48 s.f.) x (50 deg F) = 2400 Btu/hr. Total heat flow = 3918 Btu/hr.

•Problem 2: You are replacing the siding. If you add R7 polyisocyanurate rigid insulation under the new siding, how is the total wall heat flow affected?

•Answer 2: Wall = (1/(3+7) Btu/s.f./deg F) x 92 s.f. x 50 deg F = 460 Btu/hr + 2400 Btu/hr = 2860 Btu/hr. Total wall heat flow is reduced by 27%. How much would this improvement cost (assuming reworking trim and casing is not needed)?



Key concepts

In installing insulation, coverage is key.

Explanation

R-38 installed with 5% gaps and uninsulated areas yields the same heat loss as R-27 with full coverage - a 30% reduction!

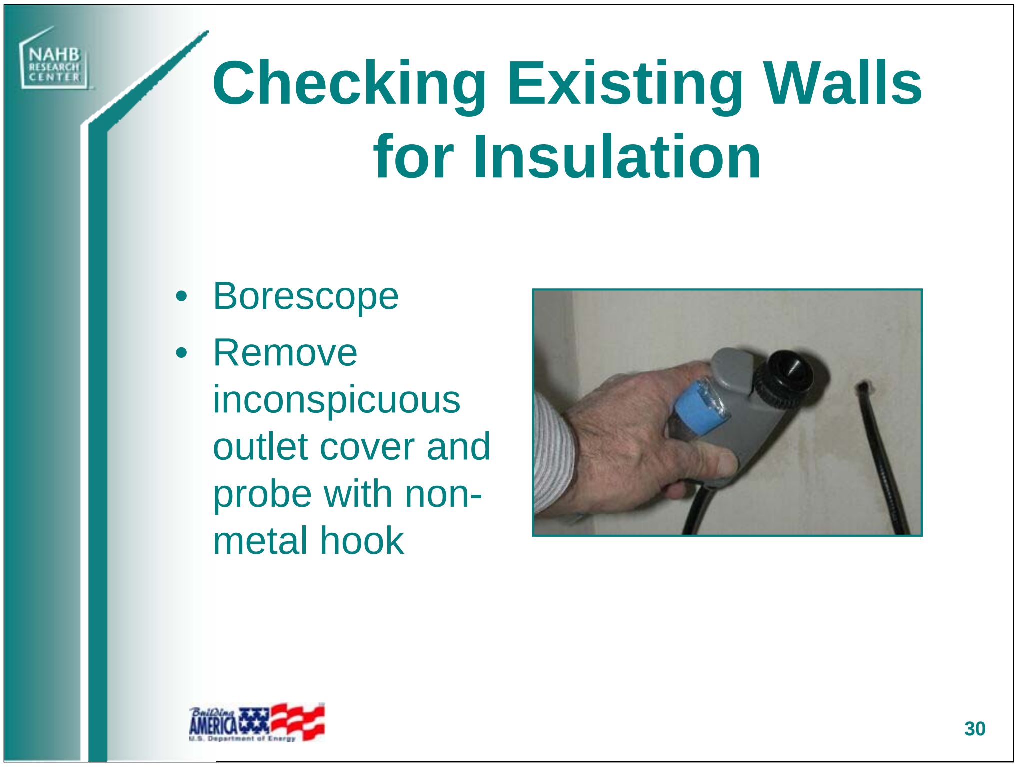
Example Problem:

Calculate the average R-value of a ceiling having 950 s.f. of R-38 and 50 s.f. of R-4.

•Ravg = (38 x 950 s.f.) + (4 x 50 s.f.) / 1000 s.f. = R-27

Action Items

Resources



Key concepts

Because wall cavities are typically concealed, various methods to determine insulation levels are needed.

Explanation

A Borescope is a device that allows you to see in inaccessible areas.

To use a Borescope you would need to drill a small hole to insert the probe.

Or to insert an actual probe, like a plastic knitting needle, remove an electrical cover plate to expose the gap between the finish wall surface and the electrical box. A knitting needle enables you to remove a small piece of insulation.

Note that removing insulation does not tell you the insulation level. Homes in the fifties and earlier in the Southeast typically had a 1-1/2 inch fiberglass batt. Other regions probably had different insulation standards and code requirements.

Note that older homes typically have had multiple remodeling projects and additions, resulting in walls with varying amounts of insulation depending on when they were built or improved.

When it is cold outside, an infrared camera may help show uninsulated cavities.

Action Items

Typical Problems with Under-floor Insulation

31

Key concepts

Floor cavity insulation has to fight gravity to stay in place, and be tight against the subfloor, in order to be effective.

Explanation

Gaps around floor insulation are common because floors tend to have many penetrations for wiring, plumbing, ductwork, gas lines, etc.

The result is that batt insulation tends to have a high failure rate in floors.

Action Items

Assure that any floor insulation provided is securely installed tightly against the subfloor.

Consider using spray applied insulation for this application. Until now only spray foam was available, but spray-applied fiberglass is being developed for this application currently. It is likely to be less expensive than foam.

Resources

Key concepts

Continuous insulation is an important detail when insulating foundation walls.

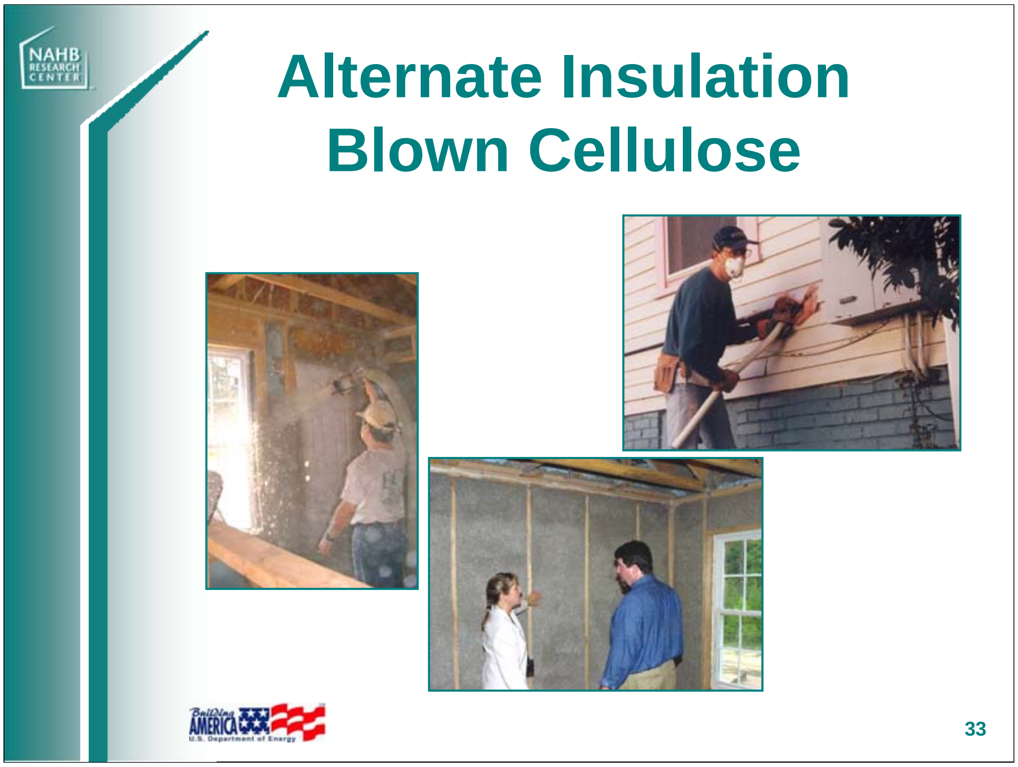
Explanation

Batt insulation (in a stud wall cavity) installed against a foundation wall typically does not fully contact the masonry wall. Subsequently, air and water vapor can get into this area and condensation can occur. Continuous insulation, like the fiberglass batts shown at right, is installed in contact with the masonry wall and the perimeter and all seams are sealed (the vinyl is perforated to allow the insulation to dry to the inside). Ideally, the insulation should not be installed in direct connection with the masonry wall as the masonry will wick moisture wetting the insulation. Current research also indicates that it is best not to install a vapor barrier on the interior in order to let the wall dry to the interior if it does get damp. Another option for continuous insulation is foam sheathing. The photo at left shows a foil faced insulation board which is code required if the sheathing is to be left exposed.

Action Items

Resources

Builder's Foundation Handbook, John Carmody, Jeffrey Christian, Kenneth Labs prepared for the U.S. Department of Energy Conservation and Renewable Energy Office of Buildings, Building Systems Division – Available at www.ornl.gov/sci/roofs+walls/foundation/ORNL_CON-295.pdf.



Key concepts

Blown insulation helps to eliminate the problems that can be associated with batts – compression, voids, missing batts. Both cellulose and fiberglass can be blown into wall cavities.

Left photo – cellulose being damp sprayed into a cavity.

Center photo – once installed, the excess is scraped off the wall surface, leaving it ready for drywall installation.

Right photo – cellulose being installed into enclosed wall cavities.

Explanation

Action Items

Consider insulation alternatives for ease of installation

Resources

Cellulose Insulation Manufacturer's Assocation (CIMA)
http://www.cellulose.org

Key concepts

Spray applied foam provides air sealing as well as insulation. While more costly to install, the results can be dramatic, particularly in finished attics. Another benefit to spray foam is sound reduction. Spray applied insulation is the most effective way to insulate the floor over an unconditioned crawl or basement.

Explanation

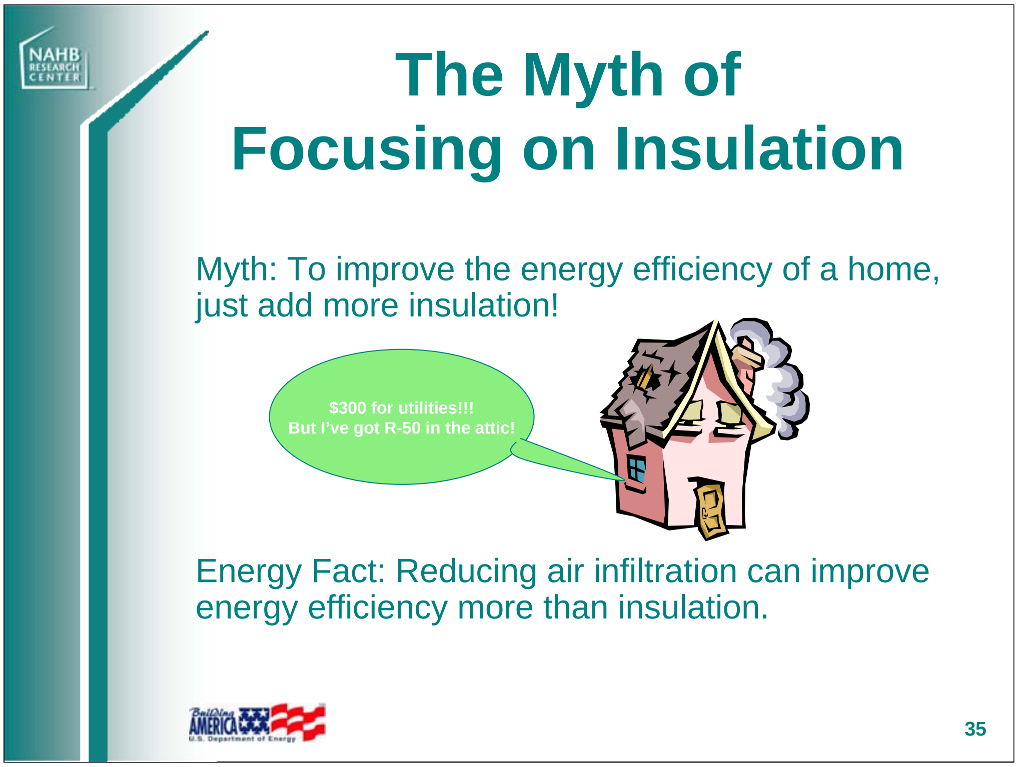
Right photo: excess cured foam is removed from the face of the wall.

Left photo: a conventional vented attic is converted to a sealed, semi-conditioned attic by spraying foam into rafter cavities and soffits to completely seal the space and provide insulation at the roofline. Note the mechanical equipment and ductwork in the bottom of the photo. In mixed and warm climates, moving the insulation and air barrier to the roofline improves energy efficiency by reducing attic temperatures and, therefore, reducing the temperature in which air conditioning equipment and ductwork operates.

Action Items

Resources

Spray foam insulation fact sheet and link to manufacturers:
http://www.toolbase.org/tertiaryT.asp?TrackID=&CategoryID=106&DocumentID=2039



Key concepts

Focusing on insulation alone to improve energy efficiency can be short sighted.

Explanation

Most homeowners and many construction professionals assume that fiberglass insulation stops air flow. As a result, they focus on improving R-value without reducing air leakage at the same time. In most cases, reducing air infiltration can improve energy efficiency more than increasing insulation.

Action Items

Resources

Air Sealing: Seal Leaks and Save Energy, U.S. DOE fact sheet, http://www.eere.energy.gov/buildings/info/documents/pdfs/26448.pdf

Tradeoffs: Increased Insulation vs. Reduced Air Leakage

	Annual Utility Bill Savings	
	ACH .80→.40	Attic Insul. R-11→R-38
Ft. Worth, TX	$162	$73
Raleigh, NC	$177	$83
Syracuse, NY	$394	$248

36

Key concepts

As the contractor, where do you recommend spending customer's money on energy efficiency improvements? It helps if you have some quantifiable basis on which to make decisions.

Explanation

This table shows how the same house in three different climates performs. Data about the house, insulation and air tightness levels, window and mechanical equipment types, floor area, house volume, and foundation information were entered into software that models the house to predict energy use. By changing inputs, like changing air tightness and insulation levels, the software can predict how these improvements affect energy consumption.

In each case, making the house significantly more air tight had a greater affect on energy use than bringing attic insulation up to current standards.

The lesson? Don't skimp on the insulation (your inspector will require you to do this anyway!), but don't forget to pay attention to air sealing.

NOTE: if both improvements were done, the savings would be less than the total of the two savings numbers, since reduced air infiltration reduces the building load and, therefore, reduces the impact of enhanced insulation levels.

It is also important to note the difference in improvement work. Air sealing tends to be much less expensive. Adding R21 blown insulation in a 2000 SF attic could cost $1500, while air sealing the basement and attic in the same house would probably cost less than $1000. Note: both prices are based on

Key concepts

There are several key strategies to control air flow in houses.

Explanation

These strategies include:

•Block infiltration and convection pathways to attics and crawlspaces. This is particularly important in cold climates where warm interior air escapes to the attic and pulls cold crawlspace air into the house.

•Seal leaky joints in walls, floors, and ceilings. Leaky joints are susceptible to both heat- and wind-induced infiltration which can impact both heating and cooling season house performance.

•Seal attic scuttles. Without effective seals, these attic access points can become “gaping holes” in the envelope of a home.

•Seal ductwork in unconditioned space. The homeowner has paid to condition this air; when it leaks into unconditioned space that effort is wasted.

•Balance pressures within the house. Pressure differentials can encourage infiltration or exfiltration and, in either case, waste conditioned air.

Action Items

Employ the strategies shown on the following slides to address critical areas of air sealing.

Key concepts

The attic is a major source of airflow pathways in homes.

Explanation

It just takes a trip up the ladder to the attic to find many sources of air leakage in a home. While not usually direct connections into the living space, the openings connect intermediate spaces like attics with wall and floor cavities. As a result, penetrations in these cavities to the interior allow unconditioned air to move into the home. Also, because these wall and floor cavities are in contact with outside air, their interior surfaces are cooled or warmed, depending on the time of year, creating unwanted heat gains or losses and potential condensation problems.

Action Items

Identify and treat airflow pathways as part of your project.

Resources

Advanced Air Sealing, http://oikos.com/library/airsealing/index.html

Key concepts

More attic airflow examples.

Explanation

Left photo: example of chase left open. The installer either ignored the opening or did not understand the impact of its being left open. A common practice is to stuff fiberglass batts into such holes prior to blowing loose fill over them—but the batts don't stop air flow!

Right photo: This chase shows a large hole into the home's interior. The customer had comfort complaints, which the builder responded to by sending an insulation contractor, who blew additional insulation (white on the far left). The customer was still uncomfortable and the next insulation contractor blew pink insulation, also with no effect. The wall of the chase facing the viewer is a wall in the master bedroom that developed mold growth because the surface temperature was low enough to condense moisture from the adjacent bathroom. Sealing this chase would have prevented condensation and the comfort issues.

Action Items

Resources

Advanced Air Sealing, http://oikos.com/library/airsealing/index.html

Key concepts

Kneewalls are often overlooked as sources of air flow in the house. However, they often connect many areas of the house. Sealing kneewalls completely can significantly reduce overall air leakage.

Explanation

Left photo – comfort complaints led the investigator into the unconditioned attic. While the house was less than 5 years old, the investigator noticed some discoloration in the fiberglass batts. Behind the batts was the back side of the bathtub.

Right photo – shows how a kneewall can be effectively sealed using rigid foam insulation board. Notice that insulation above the floor joists is a continuous layer, with seams sealed. This not only reduces air movement but the solid sheathing on both sides of the wall improves the performance of the cavity insulation, while the R-value of the board improves the thermal performance even more. Notice that the cavities between the floor joists are also sealed, making the system complete.

Action Items

Resources

Advanced Air Sealing, http://oikos.com/library/airsealing/index.html

Key concepts

Chases carry conditioned air out of the house as a result of the stack effect, fan-driven pressure imbalances in the home, and wind.

Explanation

Upper left photo – when sealing the gaps in a wet wall of the bath from the attic on a cold winter day, the installer felt air blowing in his face as he huddled over the cracks applying expanding foam.

Bottom photo and right photo – these gaps were significantly larger than the one at left and required solid sheathing sealed with caulk or expanding foam.

Action Items

Resources

Advanced Air Sealing, http://oikos.com/library/airsealing/index.html

Key concepts

Air sealing from the interior, or finished side, of the living space can help to reduce air leakage into or out of the home.

Explanation

Typically these gaps in the photos are ignored because they are concealed behind grilles and cover plates.

These air sealing details can often be done by the painting contractor, or at least at the finish stage.

Other air sealing details at completion of the project include: Caulk electrical outlets to drywall; Caulk light and fan fixtures to drywall; Caulk HVAC boots to drywall; Seal around tub drain with rigid foam board insulation and caulk or foam from crawlspace (steel wool with foam also acts as a rodent barrier); Seal attic stairs to drywall using weather stripping and latch bolts

Action Items

Include these small finishing items in the work you are planning. They will help show the homeowner your commitment to the details and quality of the job.

Resources

Key concepts

Air sealing from the attic, prior to insulation installation, can be easier than from interior.

Sealing wall top plates is usually not cost effective unless there are no obstructions in the attic.

Explanation

Photos right: air sealing a bath fan housing and electrical box with foam sheathing and expanding spray foam.

Photo left: caulk applied to the gap between the top plate and ceiling drywall.

Action Items

Resources

Air Sealing after Drywall

Attic scuttle holes must seal tight - requires weatherstripping

44

Key concepts

Attic scuttles can become a “big gaping hole” in a home’s envelope if not treated appropriately, especially since they are located at the top of a house, which is usually at the highest pressure due to the stack effect.

Explanation

The stack effect, pressure differences, wind, etc. can all cause the scuttle to leak conditioned air from the house. Attic access doors should be insulated to the same level as the attic and sealed against air infiltration.

Action Items

Install effective gasket material around the scuttle opening and seal the frame with caulk to the ceiling. Add insulation to the attic side of the door, either by attaching a fiberglass batt or rigid foam, or other material.

Resources

Key concepts

The joint between window and door frames and the rough opening can be a major source of air leakage.

Explanation

The area around windows and doors can be a substantial source of air leakage into a home that is often hard to detect once the home is complete. Chinking small pieces of batt insulation into this crack does not stop air flow. Instead, install a low-expanding foam, or caulk and backer rod, to effectively stop the airflow in this location.

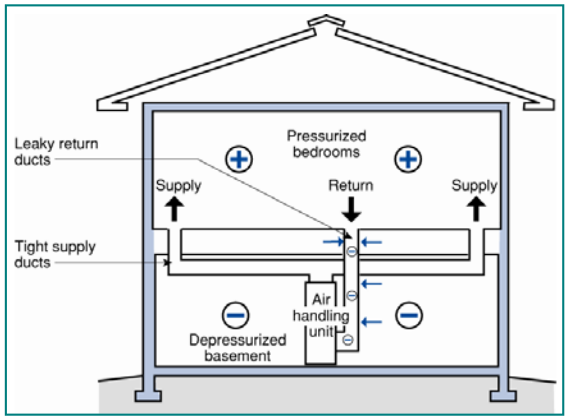
Action Items

Whenever new doors or windows are installed, seal the joint/gap between the frame and the rough opening with low-expanding foam or caulk and backer rod.

Consider removing existing door and window casing in areas being remodeled to seal the joint or gap between the frame and framing members, especially if the homeowner has identified “draftiness” as an issue.

Resources

Controlling Air Flow
Leaky Return Ducts



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Key concepts

Pressure imbalances can drive air leakage, with air leakage increasing as the pressure differences increase.

Explanation

When duct systems are located in a conditioned basement or crawl space, and there are leaks in the return ducts, the living space can become pressurized and the basement or crawl space can become depressurized as the return ducts pull in some air from the adjacent space as well as from the living space.

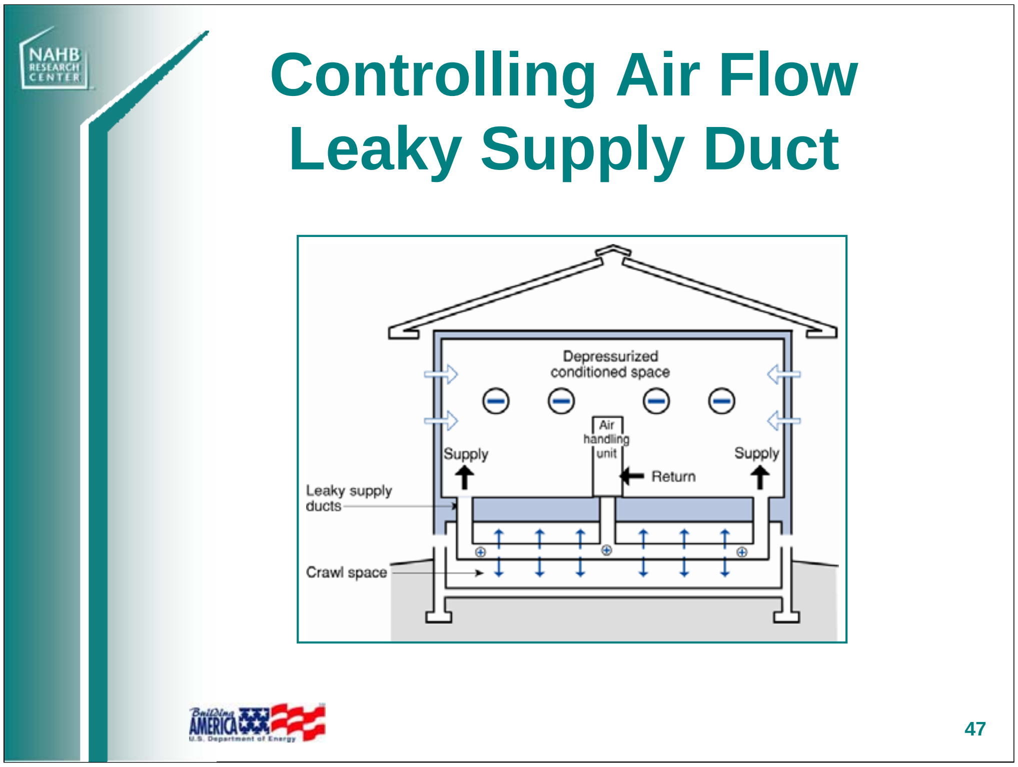
A depressurized crawl or basement can draw soil gas or outside air into the foundation area, which can then seep into the living space or be distributed in the house by the duct system.

Action Items

Seal accessible leaky ducts with mastic or aluminum tape and have the HVAC contractor balance the overall system. Leaks nearest the air handler are most critical because pressures are higher there .

Resources

Discovering Ducts, *Home Energy Magazine*, Sept./Oct. 1993, http://hem.dis.anl.gov/eehem/93/930909.html



Key Concepts

Leaky supply ducts can induce infiltration when the fan is operating.

Explanation

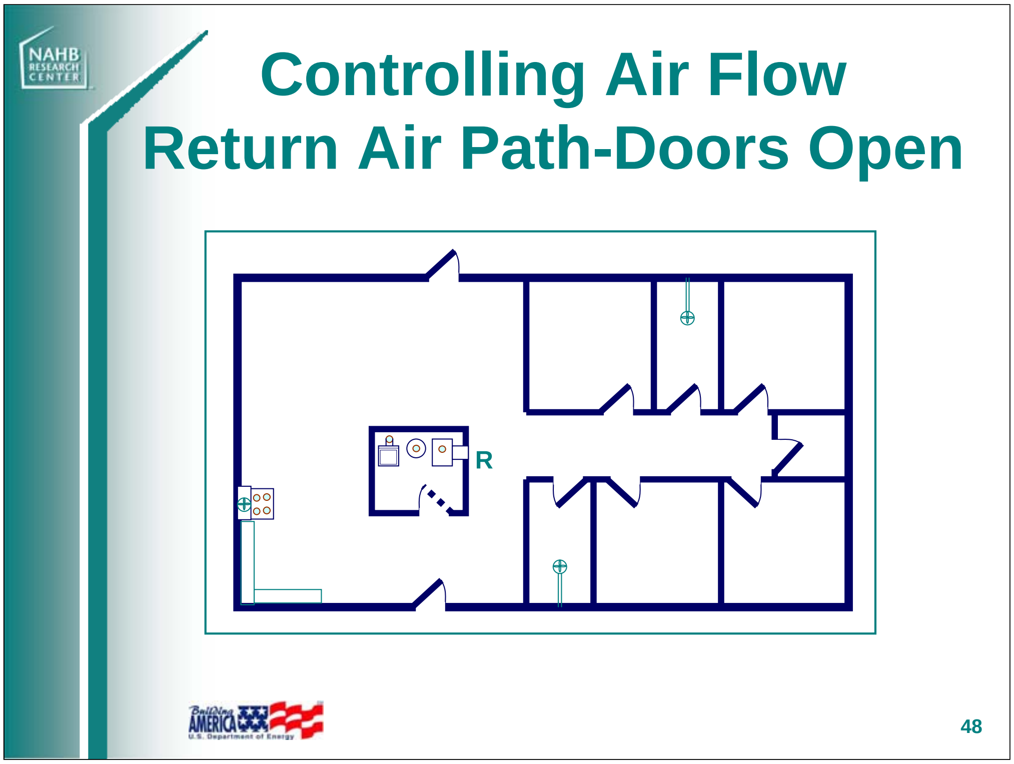
When the duct leaks are in the supply system, the reverse condition is created with pressures in the house.

A pressurized crawl space or basement relative to the interior of the house will tend to drive soil gases and other pollutants into the living space.

Action Items

Seal leaky ducts and have the HVAC contractor balance the overall system.

Resources



Key concepts

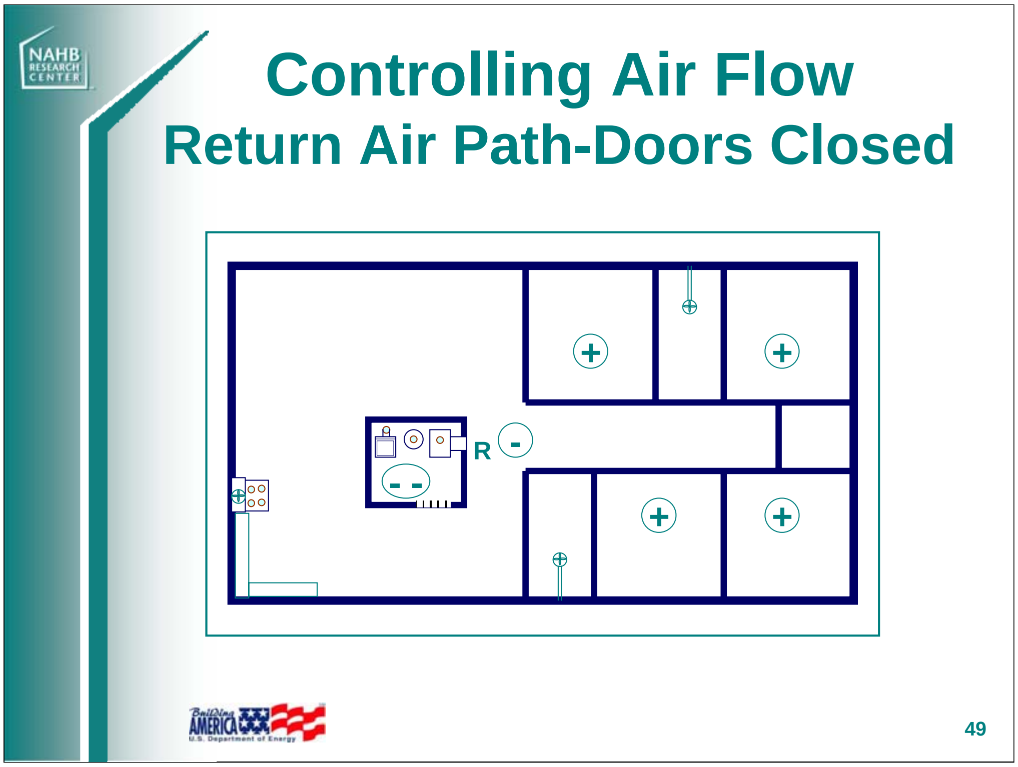
In a house with central returns, the return air pathway is critical to maintain balanced interior pressures.

Explanation

See next slide for nighttime conditions.

Action Items

Resources



Key Concepts

Return air paths are critical to good HVAC system performance.

Explanation

When occupants shut their doors and go to sleep, the house develops pressure imbalances. The bedrooms become pressurized relative to the common house areas because the supply air does not have a path back to the air handler.

These pressure imbalances can increase air leakage when the mechanical system is running, with increased infiltration occurring in the common house areas, and increased exfiltration occurring from the bedrooms. In a real life example of this, the pressures were so imbalanced that combustion gases were pulled through the closet door louver and into the duct system. Family members had to be treated for CO poisoning in a hospital with a hyperbaric chamber.

Action Items

Undercutting doors is not enough: install transfer grilles from bedrooms (or other rooms that will have doors closed for extended periods) to hallways to create a return air flow path. See the Mechanical Systems module for details.

Resources

Discussion of the Use of Transfer Grilles to Facilitate Return Air Flow in

Controlling Air Flow Sealed Crawlspaces

- Seal ground with concrete and/or plastic
- Insulate exterior walls per code
- Eliminate vents and seal leaks (e.g., access door)
- Provide dampered supply duct to space, or exhaust air from space with a radon vent or similar system

Requirements:

- No drainage problems
- If HVAC in crawl, replace with sealed combustion/ direct vent furnace or install a heat pump
- Pest Control and Code Officials approve your approach

50

Key concepts

Sealed crawlspaces offer an attractive alternative under some conditions.

Explanation

Crawlspaces typically are vented to provide outside air to reduce humidity levels. But if the moisture is controlled with foundation drainage and the dirt is covered with a vapor barrier (100%) coverage, the crawl can be treated as a 'short' basement. Then the walls rather than the floors above can be insulated. The floors are much warmer upstairs, overall energy consumption is reduced, and the costs to insulate are often no more because the surface area to be insulated is usually less than the floor surface area.

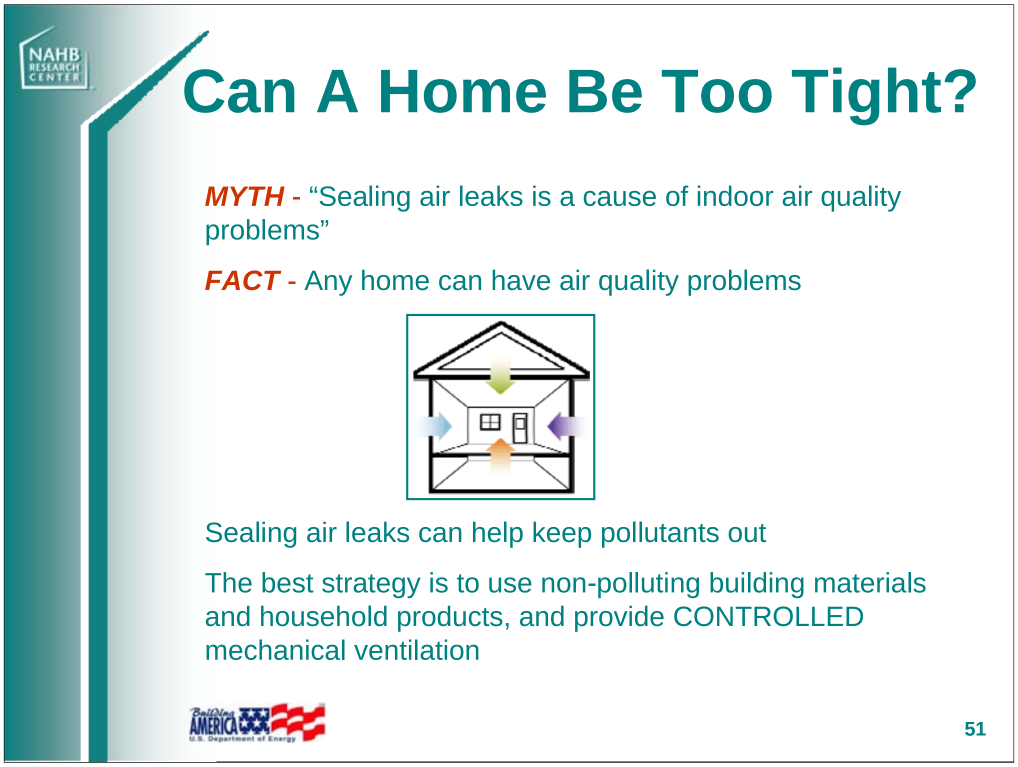
To retrofit a crawl in this way, all water intrusion must be eliminated, the furnace or other combustion equipment must be sealed combustion, electric, or be isolated in a room having its own combustion air. Also, discuss the unvented crawlspace with code inspectors and termite professionals to get their agreement in advance.

The foam on the foundation walls can be vulnerable to termite infestation, so consider using a borate-treated foam.

Action Items

Resources

Construction details for conditioned crawlspaces available at http://www.buildingscience.com/resources/foundations/conditioned_crawl.pdf



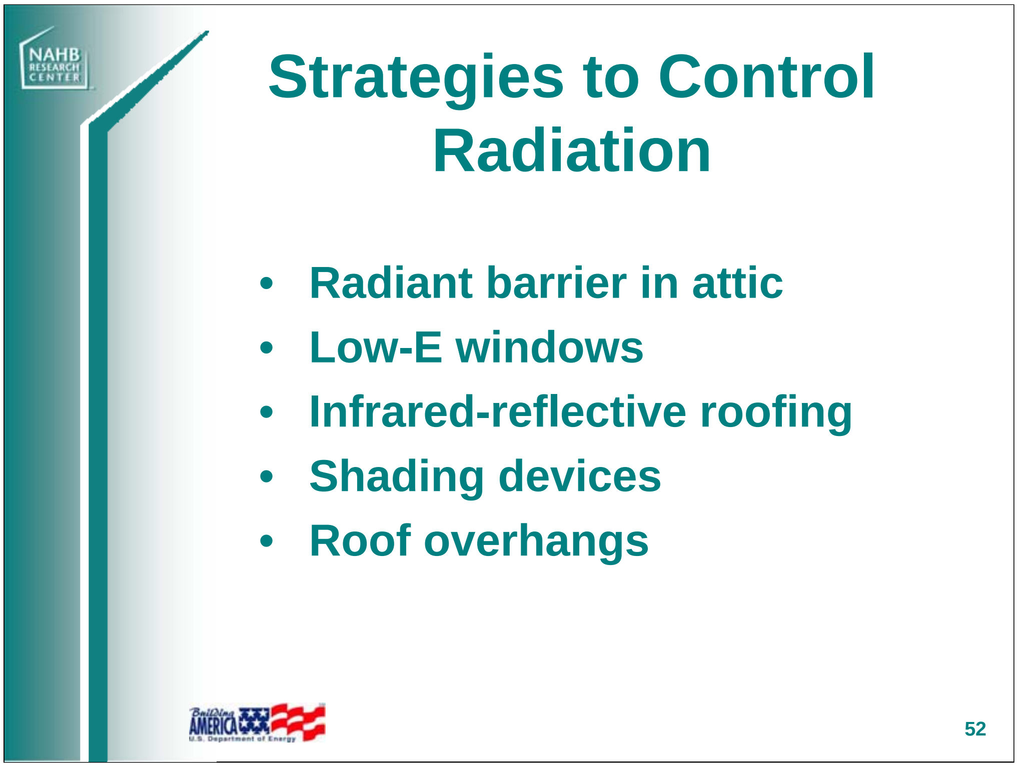
Key Concepts
Many remodelers "from the old school" believe a house must "breathe" to function properly for the occupants.

Explanation
Recenty, the opinion that homes must breathe has been reinforced because the increased use of manufactured materials that can introduce toxics and deteriorate indoor air quality (IAQ). But, if non-polluting materials are emphasized and houses are built tight with controlled intentional ventilation, IAQ can actually improve significantly. Although it can be difficult to avoid <u>all</u> materials that may contain glues or resins, one can choose low-VOC alternatives whenever possible and seal materials such as particle board cabinets that may be directly in the living space.

A leaky house provides pollutants from:
Garage….carbon monoxide
Attic….hot air, dust, rat scat
Outside…humidity, allergens
Inside…formaldehyde-laden furniture, tobacco smoke, volatile organic carbon (VOC) emissions from paint, carpet
Crawlspace…mold, mildew, radon, humid crawlspace air from vented crawls
If you live in a leaky house, you might need to wear a respirator!

Action Items

Resources



Key Concepts

We will look at three strategies to control solar radiation in remodeling.

Explanation

In cooling-dominated climates, radiant barriers can be installed in newly constructed attics or retrofit into existing ones to reduce the radiation of heat from the attic roof.

Low-E glazing is easy to add whenever new or replacement windows are part of the project and can be part of a strategy to limit solar heat gain.

Infrared-reflective roofing materials can be used on additions or when re-roofing the entire house. Metal and tile reflective roofing is available; conventional shingle roofing is under development.

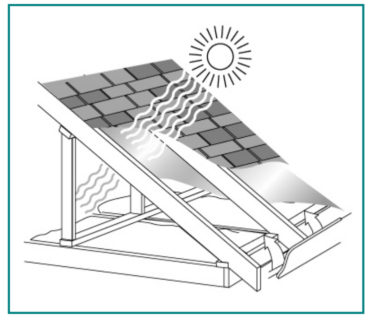
Extending roof overhangs above south-facing windows can be an effective way to reduce summer solar gains. Usually, the overhang will need to be at least 18” – 24” to provide adequate shading. Because the sun is lower in the sky in the winter, you can still get the beneficial solar gains in the winter.

Action Items

Resources

Cool Roofs Rating Council, http://www.coolroofs.org

Controlling Radiation
Radiant Barriers



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Key concepts

Radiant barriers are reflective materials that can reduce summer heat gain in attics. They can also reduce heat loss (see basement photo with foil faced insulation sheathing). They are particularly effective in homes in cooling-dominated climates where cooling equipment and ductwork is contained in the attic.

Explanation

Radiant barriers work two ways: they reflect thermal radiation well and they emit (give off) very little heat.

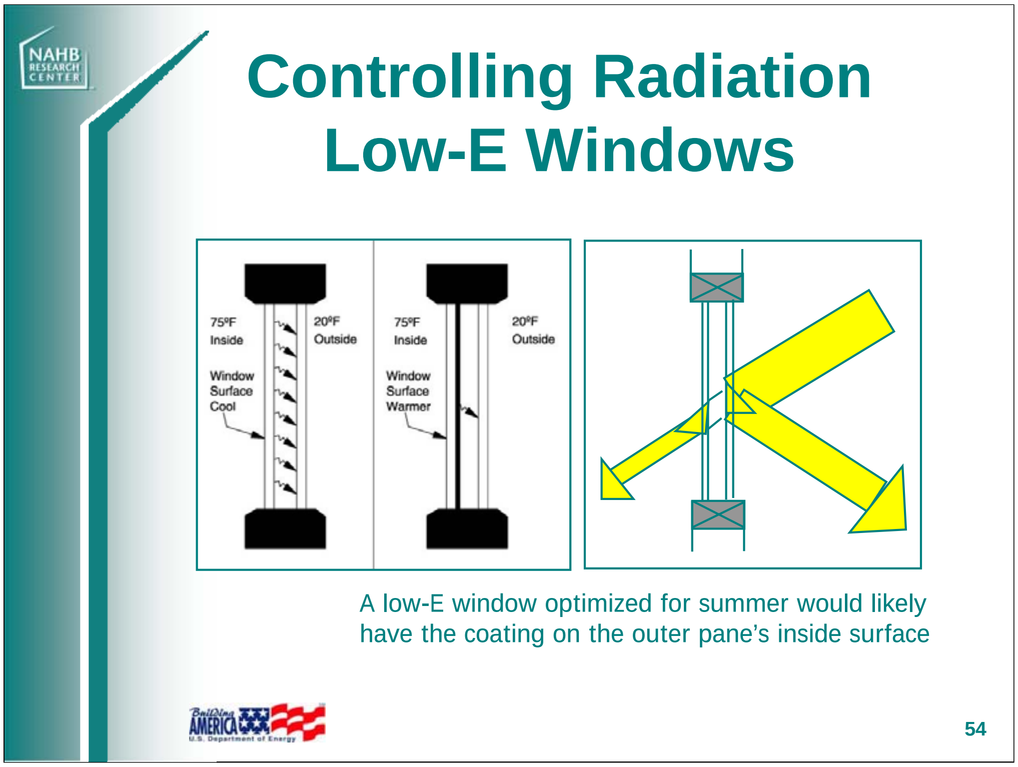
Radiant heat barriers need to face an airspace and be installed to prevent a dust buildup. On the attic side, if materials are in contact with the barrier, heat is transmitted by conduction and the low emitting qualities of the material are negated.

Action Items

Resources

Reflective Insulation Manufacturers' Association, http://www.rima.net

Radiant Barriers, a Question and Answer Primer, Florida Solar Energy Center, http://www.fsec.ucf.edu/pubs/energynotes/en-15.htm



Key concepts

Low-E glazing in windows can significantly lower the heat gained or lost through windows. Solar Heat Gain Coefficient is a number between 0 and 1 that indicates the amount of solar radiation that passes through the window as heat.

Explanation

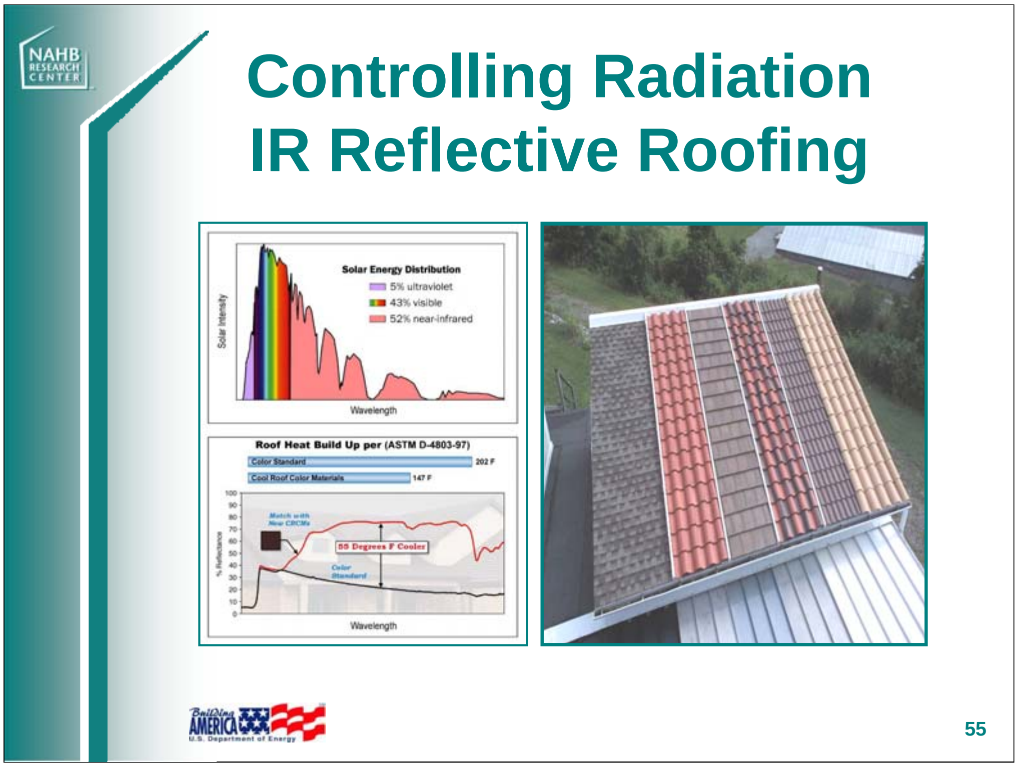
Low-E glazing reflects the radiant portion of heat transfer through glass. Low-E coating can be placed on one of four surfaces in a double-pane window. Placing the Low-E coating on the inside pane's outer surface helps to reflect the house's interior warmth back in the winter and is best for northern climates. Placing the Low-E coating on the outside pane's inner surface help to reflect summer's heat back outside. Windows that are low-E and have low SHGC are often called low-E squared or spectrally selective.

Action Items

Select an ENERGY STAR window for your climate when replacing windows. For more advanced passive solar design, select windows with high Solar Heat Gain Coefficient for the south face and a low SHGC for all other orientations. When selecting high SHGC for south-facing windows, be sure there are sufficient overhangs to provide shading in the summer months.

Resources

http://www.efficientwindows.org – Website that provides information about



Key concepts

In hot climates infrared (IR) reflective roofing can dramatically lower roof and attic temperatures and, therefore, the house's cooling load and utility costs.

Explanation

The photo on the right shows a range of IR reflective metal and tile roofs in various colors undergoing field testing at the Oak Ridge National Laboratory. Note that the colors are the "darker" tones preferred by most homeowners. The chart in the upper left shows that 52% of the solar energy hitting the roof is IR and can be impacted by IR reflective materials in the roofing. The chart in the lower left shows that a roof with IR reflective materials is 55 degrees cooler than the same color roof using standard materials.

Note: In cold climates, the benefit of IR reflective roofing in the summer may be more than offset by the liability of a "cooler" roof and attic in the winter.

Action Items

For hot climates, investigate the use of IR reflective roofing if the house requires a new roof or if a major addition is being planned.

Resources

Cool Roofs Rating Council, http://www.coolroofs.org/

Strategies to Control Moisture Flow

- Bulk moisture at foundations
- Bulk and vapor moisture at walls
- Bulk moisture at window flashing
- Bulk moisture through design
- Vapor moisture with material's permeability

56

Key concepts

We will look at five keys strategies to control moisture flow in houses.

Explanation

Bulk moisture at foundations – liquid water that gets into the basement or crawl space

Bulk and vapor moisture at walls – rain and humidity induced moisture

Bulk moisture at window flashing – rain entering around window frames

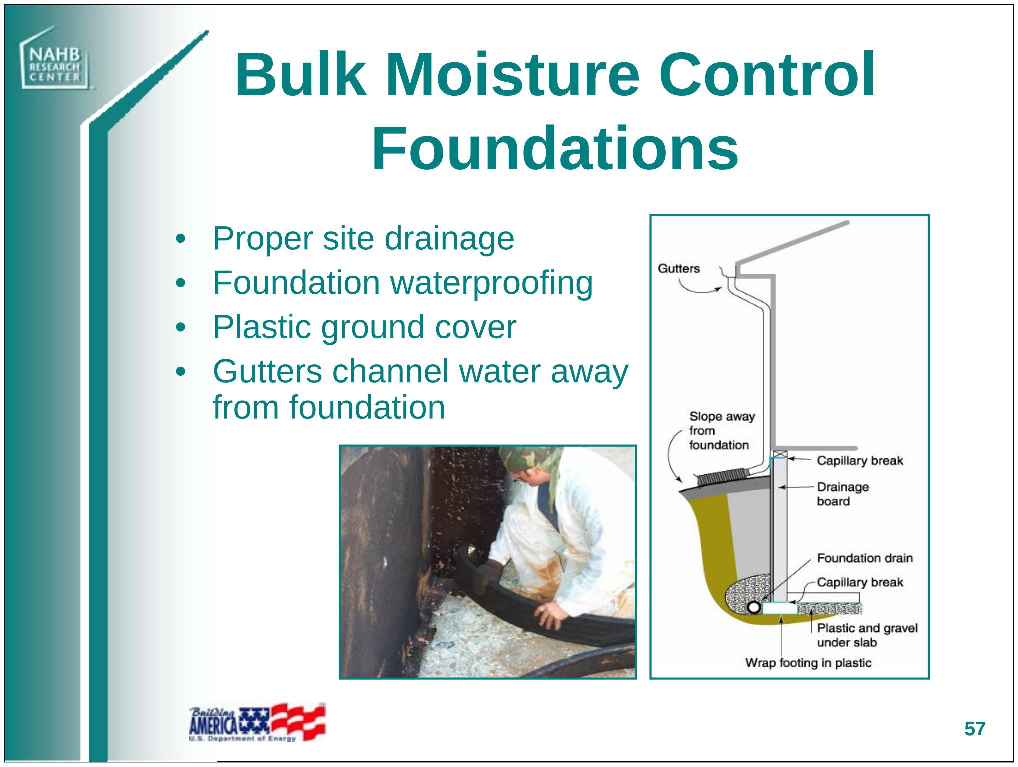
Bulk moisture through design – avoiding the "dumb" things that drive water into a house

Vapor moisture with material's permeability – using the right materials is very important

Action Items

Resources

Moisture Control Handbook: Principles and Practices, Joseph Lstiburek and John Carmody – available through the Energy and Environmental Building Association- www.eeba.org



Key concepts

Site drainage, foundation waterproofing, and channeling water away are key strategies in foundation moisture control.

Explanation

Proper site drainage helps ensure water flows away from foundation walls. Gutters with downspouts should carry water at least five feet away from the building or into underground drains to ensure the water from the roof and surrounding soil is unlikely to make its way back to the building.

If water moves toward the foundation wall, a membrane coating on the foundation keeps water from passing through the wall. However, these systems are prone to damage as foundations settle and shift and can be damaged during backfill or can deteriorate over time.

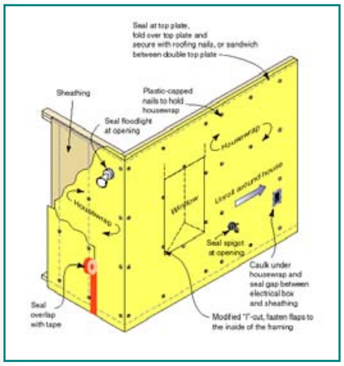
A good backup to foundation coating is a drainage board placed over the coating. Since water will seek the path of least resistance, the drain board easily allows the water to move downward to the foundation drain placed either on or beside the footing, which channels the water away from the building.

Action Items

Resources

Durability By Design – A Guide for Residential Builders and Designers, prepared for U.S. Department of Housing and Urban Development,

Bulk and Vapor Moisture Walls (Housewrap Weather Barrier)



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Key concepts

Housewrap can assist in bulk and vapor moisture control in walls. Just like Gore-Tex jackets, it prevents rain from passing through, but allows water vapor to escape.

Explanation

In above grade walls, water must also be managed. Cladding systems, whether brick or stucco or siding, can and do leak.

It is very important to make provisions for moving water out of a building when it gets past the cladding and to prevent it fro reaching the structure.

Any system is only as good as its weakest points. Penetrations such as windows, and transitions such as where a sidewall meets a roof, are examples of weak points in the cladding system.

Housewrap is a modern equivalent of tar paper or felt and is used to prevent water from getting into the structure. Housewrap must be integrated with flashing systems at roofs, windows, and other penetrations.

Action Items

When re-siding an existing home or installing new siding on an addition, install a housewrap beneath the siding to assist with diverting bulk water away from penetrations and with providing an air barrier. Follow manufacturer's installation instructions, making sure that housewrap extends into window openings and that seams are lapped shingle-style and taped.

Bulk Moisture Control
Walls - Housewrap Details

Top Sash after trim removed

Rotten Header

Windows (incorrectly) have flange over housewrap

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Key concepts

When installing housewrap, always think “shingle style” about water – it runs downhill.

Explanation

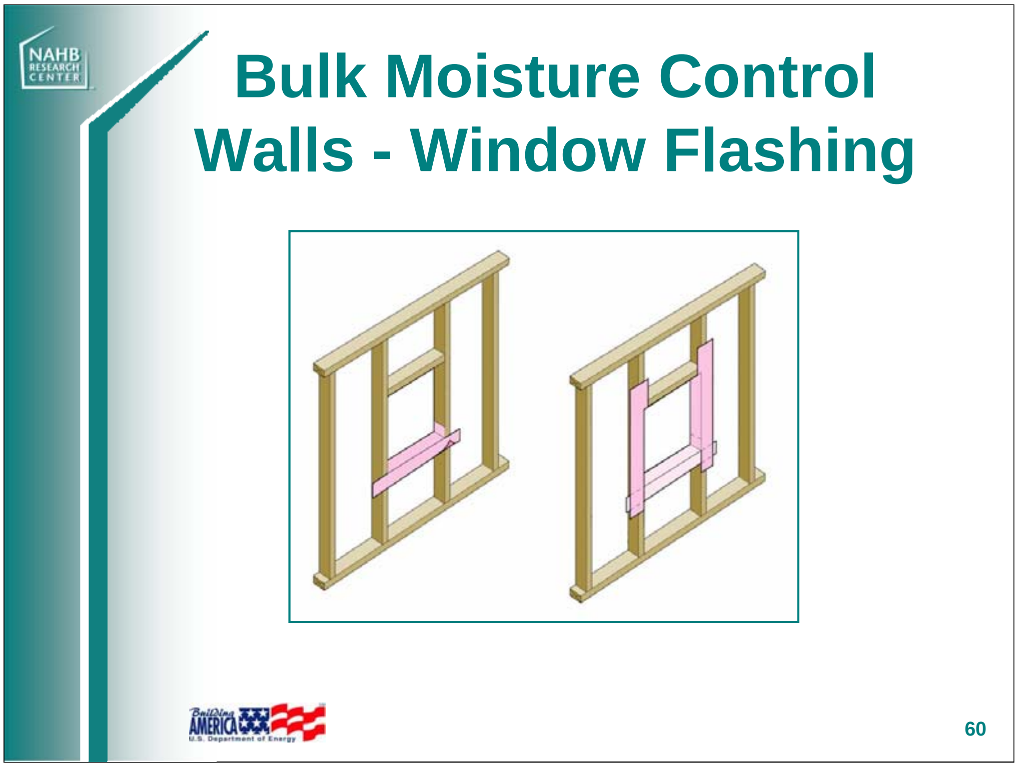
In the top left photo, owners of a less than 10-year old house noticed discoloration and occasional water at the top of the windows.

In the lower photo you can see that when the siding was removed to investigate further the window flange is overlapping the housewrap at the top of the window, the reverse of shingle style.

In the upper right photo you can see the condition of the header over the window when the housewrap was removed – significant rot.

Action Items

Resources



Key concepts

When installing windows, a flashing system must integrate the housewrap or felt with the window opening.

Explanation

This drawing shows a three-step process to creating this integration. First, sheathing is removed for clarity. This process can work when the windows are to be installed prior to the housewrap or felt.

<u>Sill flashing.</u> In the left photo, the horizontal flashing at the window opening bottom is installed. Fasten the top edge of the sill flashing to the wall sheathing but do not fasten the lower edge, so that the drainage plane applied later may be slipped up and under the flashing “shingle fashion”. Extend sill flashing horizontally 16 inches to project beyond the vertical jamb flashing applied later. The sill flashing is folded over the bottom of the rough opening of the window and then vertically along the jack studs several inches .

<u>Jamb flashing.</u> Install side pieces of jamb flashing. Fold jamb flashing around the side of the rough opening and over upturned sill flashing. At the top, the jamb flashing at both sides of the opening extend beyond the sill flashing and above where the head flashing will intersect. Lap jamb flashing over top of sill flashing leaving bottom edge unattached.

<u>Head flashing</u> (not pictured). Install head flashing to extend horizontally onto the window and vertically at least 6” onto the sheathing. The housewrap or felt will be installed over the vertical leg, shingle style.

Key concepts

When roofs direct water toward sidewalls or adjacent roof areas the potential for water intrusion grows.

Explanation

Another common practice with complex roof designs is for water to be channeled from a large area through a small passage, creating the potential for water to back up under claddings. In addition these narrow passages terminate on a section of fascia too short for adequate gutter and downspout capacity. Water can wash over gutters and erode soils below, and even penetrate foundations.

Action Items

Avoid roof designs that significantly increase the risk of water intrusion and other water related problems.

Resources

Vapor Moisture: Materials (Permeability)

Material	Perm
Drywall	30-50
Housewrap	5-50
Semi-gloss latex enamel	6.6
Primed & Painted Drywall	2-3
Interior plywood	1.9
15 pound asphalt felt	1-4
Insulated foam sheathing	0.4-1.2
Exterior plywood/OSB	0.7
Vapor retarder paint	0.6-0.9
Asphalt coated kraft paper	0.4
Polyethylene	0.06

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Key concepts

All building materials have a permeability (perm) representing the rate at which they allow water vapor to pass through. The lower the number, the less vapor permeable is the material.

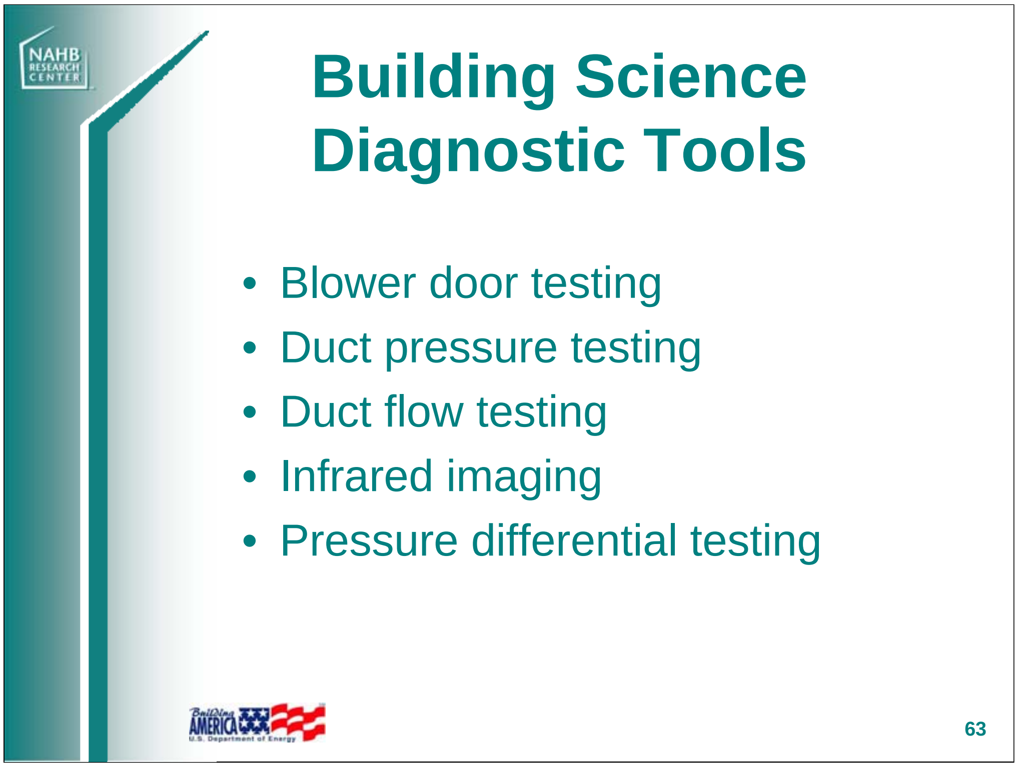
Explanation

Generally, materials having a permeability lower than 1 are considered vapor barriers.

The permeability of some materials, such as asphalt building paper, varies with the moisture content of the material. Notice that housewraps usually have a high perm rating, which permits vapor to pass out of the structure while the wrap prevents liquid water from getting in. However, perm ratings of housewraps vary from manufacturer to manufacturer.

Knowing what materials you are installing in different assemblies is critical to ensuring that any assembly (wall, roof, floor) can dry to the inside, outside, or in both directions if the assembly get wet. Planning for the drying of an assembly is critical since most manufactured and engineered materials (drywall, OSB, insulation) wick water and can deteriorate more rapidly than solid sawn lumber and plaster. The need to plan is greater with modern homes, since the effect of insulation slows drying because less heat is moving through the assembly to help evaporate the water.

The photo shows the effects of installing polyethylene, with a perm rating of 0.06 on an interior wall in a mixed climate. A roof leak was not detected until the water had done extensive structural damage. Further, the poly ensured that the wall could not dry to the interior, hastening its decay.



Key concepts

There are a number of diagnostic tools available to help you understand how a home performs and why. Diagnostic testing also can confirm the effectiveness of improvement work such as duct sealing. Diagnostic testing frequently surprises many conscientious heating and cooling contractors when it shows that their systems are leakier than they had assumed.

Explanation

The five commonly used tools include:

- Blower door testing
- Duct pressure testing
- Duct flow testing
- Infrared imaging
- Pressure differential testing

Action Items

Resources

The Energy Conservatory, http://www.energyconservatory.com, look under "Articles → linked articles"

Key concepts

A blower door is a device that is installed in an exterior door and has a calibrated fan that can quantify air leakage in a home.

Explanation

Blower doors can be a powerful educational and sales tool for remodelers. Most customers are amazed at what it demonstrates about their house.

In a blower door test, the fan is used to pressurize or depressurize the house to a standard test pressure (typically 50 Pascals). The fan flow at this test pressure is the amount of air that is leaking into or out of a home at that pressure. By using the house geometry, this fan flow is typically translated into Air Changes per Hour or equivalent leakage area.

Action Items

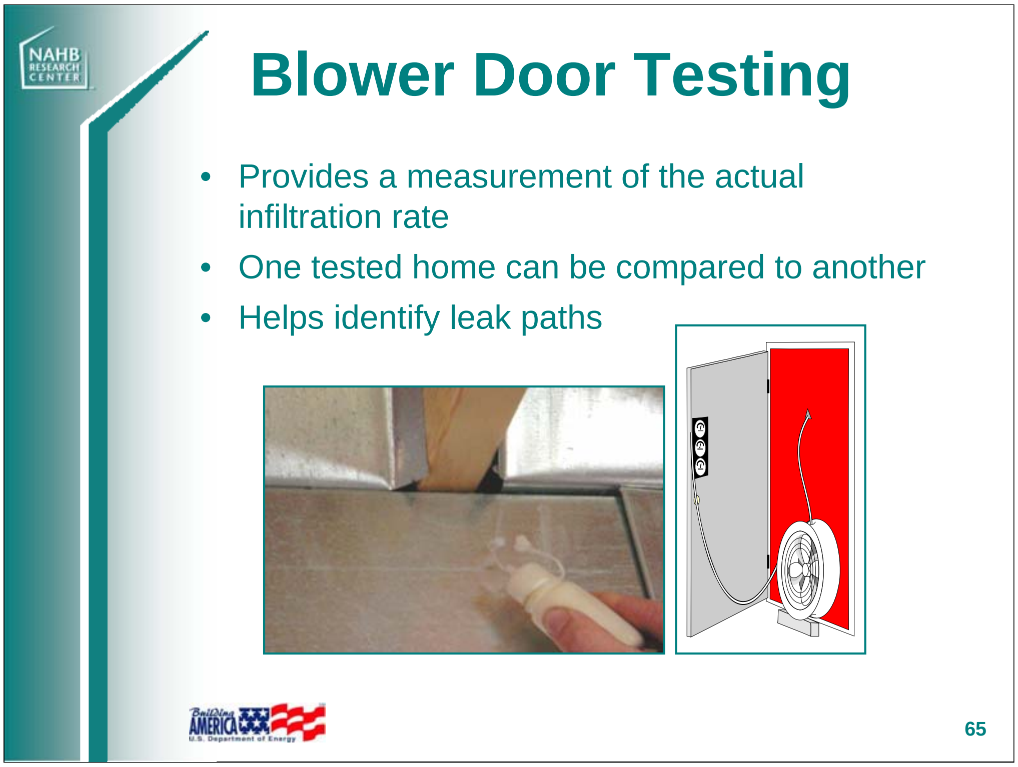
Consider using blower door testing to help diagnose the condition of a home before and after a major remodeling project.

Check with your insulation contractor, local weatherization agency, or local utility to see if they perform blower door and/or ductblaster testing.

Resources

Database of Home Energy Raters that are qualified to do blower door testing, http://www.energystar.gov, look under "partners"

Blower Door fact sheet,
http://www.toolbase.org/tertiaryT.asp?TrackID=&CategoryID=1392&Docume



Key Concepts

Explanation

The leakage rate determined by a blower door test can tell you how leaky the home is—the tightest new homes today rate about 1.5 ACH50, but without mechanical ventilation, the tightest a home should be, approximately, is 7 ACH50. This information can allow you to compare the home to other homes of similar vintage and can be used in before and after tests to demonstrate the improvements you make to the home.

When the fan is running you can also identify leakage paths with chemical or powdered 'smoke'. (Or even by feeling around typical culprit areas such as windows and doors.)

The photo shows how smoke from the white bottle is drawn into the duct leak. Another technique is to go into the attic while the fan is depressurizing the house, generate smoke, and look to see where it is being drawn into the home.

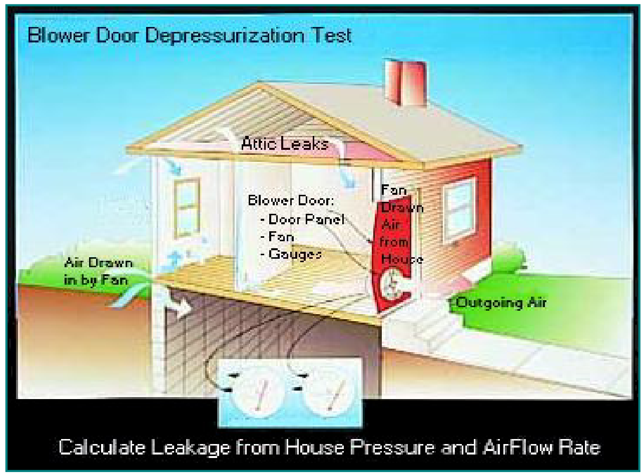
Action Items

Resources

http://www.energyconservatory.com

http://www.retrotech.com

Blower Door Testing



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Key Concepts

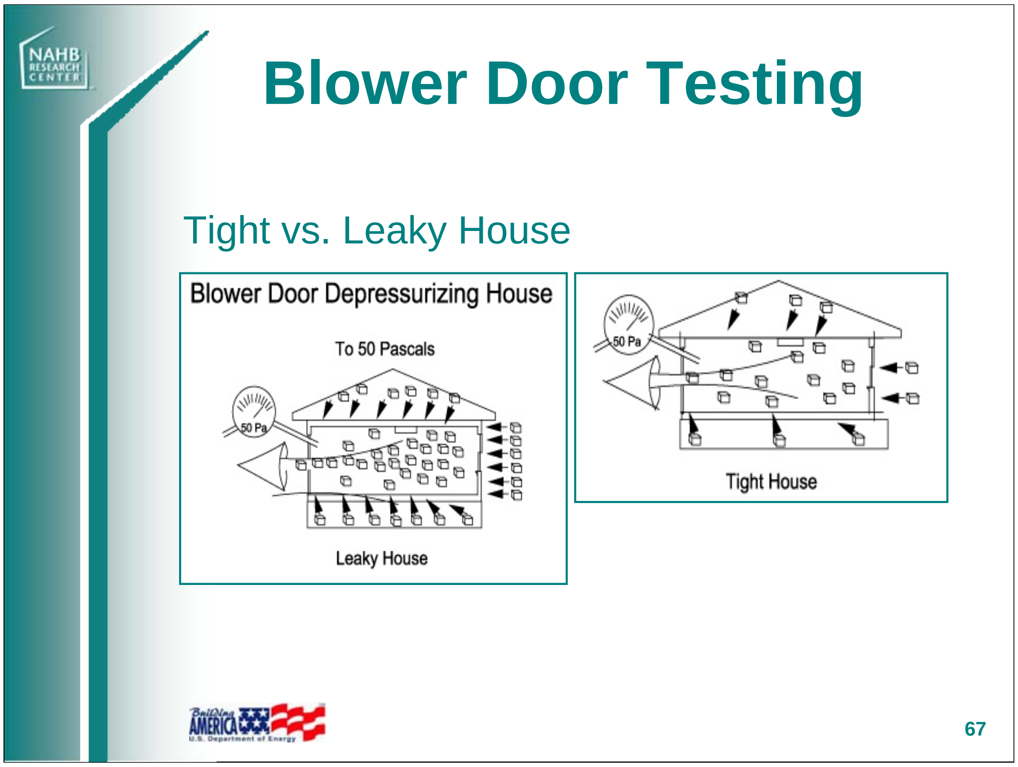
Schematic drawing of a blower door test.

Explanation

Diagram shows where air leakage can occur while the fan is running – through leaks in the ceiling, windows and doors, where the foundation meets the wood structure, among others.

Action Items

Resources



Key Concepts

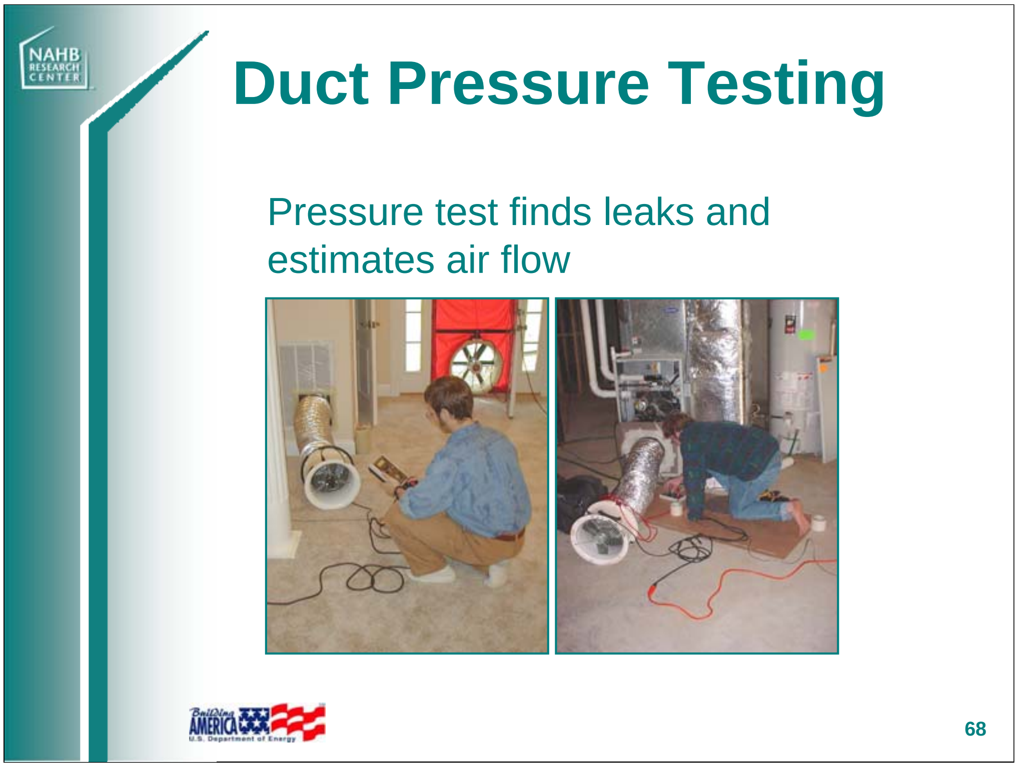
Explanation

(See diagram) When the blower door fan is pulling air out of a house (depressurization mode), it needs to pull more air out of the house to maintain that pressure difference for the more leaky home.

In the above diagrams, each box or “milk crate” equates to 1 cubic foot of air.

Action Items

Resources



Key concepts

Duct leakage is also a significant source of energy loss in homes when the ducts are located outside the conditioned space such as in attics or basements or crawls. Duct leakage can also enhance house air leakage.

Explanation

Measuring the leakage in ducts is similar to measuring envelope leakage with the blower door.

The duct fan is smaller than the blower door, but is calibrated like the blower door so that, when the fan creates a standard pressure difference, the volume (CFM) of air movement is referenced to either the floor area served by the system or the air handler fan capacity. For example, test results are often given as a percentage of air handler capacity or floor area.

A duct blaster can also be used to identify leak locations so these leaks can be sealed.

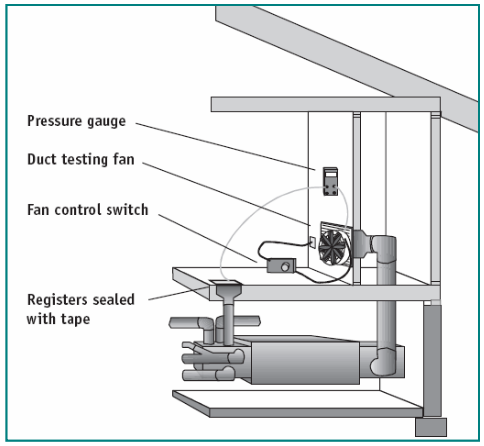
Action Items

Resources

Duct Leakage Testing fact sheet, http://www.toolbase.org/tertiaryT.asp?TrackID=&1292&DocumentID=2027&CategoryID=28

Duct Pressure Testing

Basics



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Key Concepts

Explanation

To test duct tightness, supply and return ducts are sealed at registers except where the fan is attached. The fan is switched on to create the pressure difference inside the ducts in order to determine the flow of the fan.

Action Items

Resources

http://www.energyconservatory.com

Key concepts

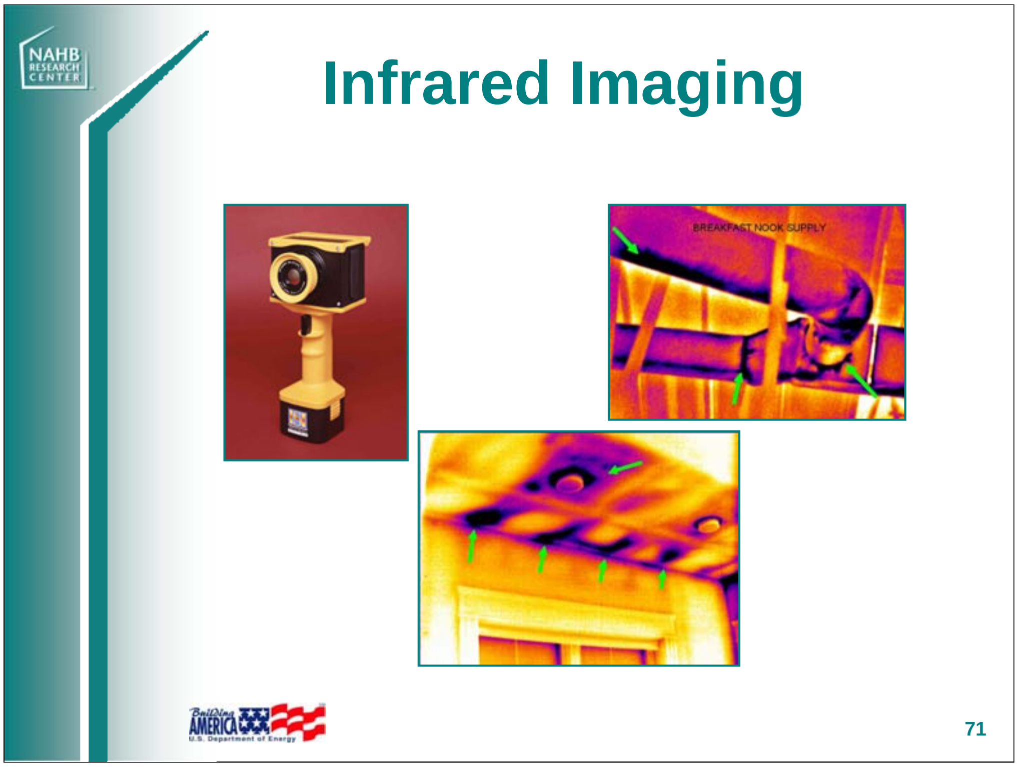
Another approach to measuring duct system performance is to measure the flows into and out of the grilles, add the supply air and return air separately, and compare this to what the intended system flow. The device used for this test is called a flow hood.

Explanation

Some professionals prefer to focus on what the system puts into or takes out of the house to measure duct system performance rather than looking for the leakage out of the system. The first focuses more directly on comfort and the latter tends to focus more directly on energy loss. There are times when both pieces of equipment are needed to get a complete picture of how the system is performing. For example, if a customer complains about inadequate heating and the flow tests report that there is inadequate supply flow, the cause could be insufficient supply registers (too small or too few), impaired airflow, or both.

Left photo is an Alnor flow hood. Right photo is the eScan equipment. This system uses flow hoods connected wirelessly to a laptop computer for instant reporting, and also includes tools to measure condensing unit airflow and static pressures. It is a more comprehensive diagnostic tool used mostly by HVAC professionals.

Action Items



Key concepts

IR cameras can detect temperature differences and show this graphically like a photo, with temperature differences displayed with color.

Explanation

The least expensive professional unit on the market is a handheld model (photo left).

Center photo: the purple and blue areas are of lower temperature around recessed lights showing air flow through the lights.

Ideal for finding missing or poorly installed insulation and other thermal defects.

When used in conjunction with a blower door, IR imaging can easily identify air leakage sites that are buried deep inside ceiling, wall, and floor assemblies.

Action Items

Resources

http://www.energyconservatory.com

Infrared Thermometer

- Less expensive than IR camera
- Provides instant reading of surface temperature
- Less complete a graphic result than IR camera, but still useful

72

Key concepts

Infrared thermometers can be used to locate heat flow problems in house envelopes and ductwork.

Explanation

Provides a less expensive alternative to IR cameras.

Does not provide the graphic benefits of the IR camera.

Action Items

Resources

http://www.professionalequipment.com

Digital Manometer

- Detect pressure differentials between rooms
- Detect combustion safety problems – backdrafting water heaters and furnaces

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Key concepts

Manometer is part of the blower door and duct blaster setups, but can be used alone to diagnose pressure differences between rooms and zones of a house.

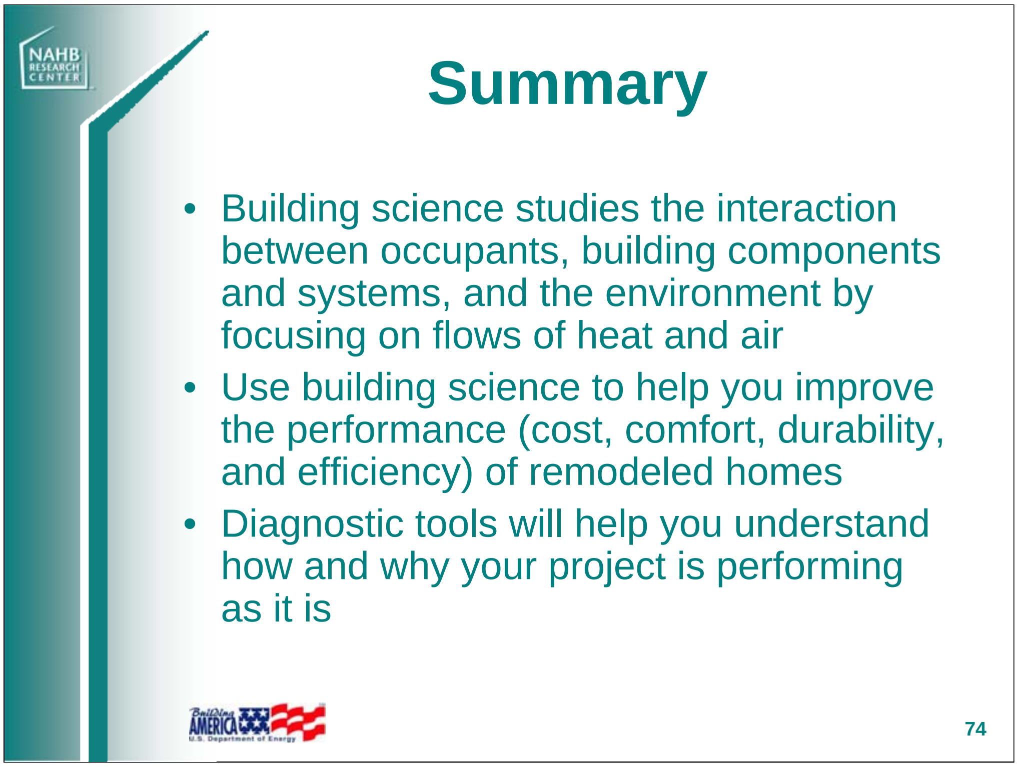
Explanation

When combustion equipment is located inside living areas, pressure differences can create a condition where exhaust gases are actually drawn down flues and into the home. This can be a dangerous situation. In addition, a pressure differential (typically greater than 3 Pa between rooms) can lead to inadequate supply and return air (leading to room stuffiness, enhanced infiltration/exfiltration, too cold/too hot, or other issues).

A digital manometer is an easy way to view potential pressure differences. To detect the pressure difference between two rooms when a fan or the air handler is running, turn the fan on and close the door between the two rooms of concern. Attach a length of tubing to one side of the manometer and slide the other end under the door (Room B). Keep the manometer in Room A; thus, the open ports on the other side of the manometer will “see” the pressure in that area. Turn the manometer to the pressure reading setting and read the difference in pressure between the two rooms. The reading will be given in Pascals.

Action Items

Resources



Key concepts

This module has introduced you to building science and how it can improve the homes you remodel.

Explanation

This module has presented the basics of building science and has shown you through examples how you can better understand how and why homes perform as they do. This knowledge will enable you to provide a better product to your customer in terms of cost, comfort, durability, and efficiency. A better product will enhance your market position.

The benefit of using building science in your activities is that, by implementing the process of investigating, analyzing, evaluating options, and implementing the best option, your final product improves with each use. Current and future projects will benefit from your previous building science efforts.

There are a number of diagnostic tools and services available that can improve your understanding of how and why your project is performing as it is. These tools can also be used to show your customers that your house project are superior to those done by other remodelers.

Action Items

Start applying building science to improve your remodeling projects. Identify and use the tools that will be most beneficial to you. Market your superior homes to your customers.